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AUTHOR	Teague, Cash; Pewewardy, Garner
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ABSTRACT

This curriculum guide, part of a series of industrial electricity curriculum guides, consists of materials for use in teaching a course on the in-plant distribution of electricity. Discussed in the introductory lessons are the National Electrical Code, power equipment, and blueprint reading. The next section, a series of units on branch-circuit wiring, comprises discussions of interrupting devices, conductors, electrical raceways, and boxes and enclosures. Covered in a section on feeder-circuit wiring are units on in-plant distribution systems, in-plant distribution equipment, and electrical diagrams. Concluding the guide is a unit on solid-state devices. Each instructional unit contains some or all of the following: performance objectives, suggested activities, information sheets, transparency masters, assignment sheets, job sheets, tests, and answers to the test and assignment sheets. (MN)

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Industrial Electricity

In-Plant Distribution

Written by

Cash Teague and Garner Pewewardy, Curriculum Writers
State Department of Vocational and Technical Education
Stillwater, Oklahoma

John Humler
Technical Consultant

Joyce Sawatzky, Assistant Coordinator
State Department of Vocational and Technical Education
Stillwater, Oklahoma

Developed by the
Curriculum and Instructional Materials Center
Bob Patton, Coordinator
for the Division of Trade and Industrial Education
Ivan Armstrong, State Supervisor
Oklahoma State Department of Vocational and Technical Education
Francis T. Tuttle, Director
Oklahoma State Board of Vocational and Technical Education
Leslie Fisher, Chairman

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INDUSTRIAL ELECTRICITY: IN-PLANT DISTRIBUTION

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FOREWORD

We believe that vocational education increases its usefulness in preparing students for occupations through the use of high quality competency-based instructional materials. As we began to develop instructional materials needed to train industrial maintenance technicians, five distinct instructional areas evolved: industrial electricity, industrial electronics, hydraulics, pneumatics, and electromechanics. In order to address the competencies required by industrial electrical workers, we found that three separate instructional products were needed: *Introduction to Industrial Electricity/Electronics; Industrial Electricity: Motors;* and *Industrial Electricity: In-Plant Distribution.*

Introduction to Industrial Electricity/Electronics is designed to instill those basic knowledges and skills needed by any worker in the industrial maintenance field. Units of instruction include orientation, electron theory, circuit theory, test instruments, basic electronic components, and fabricating skills.

The second publication, *Industrial Electricity: Motors,* provides instructional resources needed by students who choose to specialize in an industrial electrical occupation. The manual focuses on competencies needed in the areas of DC motor systems, AC motor systems, and motor generators.

Thirdly, we found a need for a publication to assist students in developing skills associated with power distribution and solid-state devices. Hence, *Industrial Electricity: In-Plant Distribution* is presented. This publication addresses skill and knowledge training in four separate areas: Introduction to Industrial Electrical Wiring; Branch Circuit Wiring; Feeder Circuit Wiring; and Solid-State Devices.

Rapid technological advancements require that skilled workers be able to adapt to their changes. Through the use of *Introduction to Industrial Electricity/Electronics, Industrial Electricity: Motors,* and *Industrial Electricity: In-Plant Distribution,* a student should be able to enter the work force as a productive, competent worker.

Francis Tuttle, Director
Oklahoma State Department of
Vocational and Technical Education

Ivan Armstrong, State Supervisor
Trade and Industrial Education

PREFACE

Not only must individuals in today's workforce be competent, but they must be willing to meet the many changes evolving from technological advancements. Industrial maintenance technicians face unique challenges in their work. The field of industrial maintenance includes five separate specialities: industrial electricity, industrial electronics, hydraulics, pneumatics, and electromechanics.

Industrial Electricity: In-Plant Distribution is one of the few instructional products, if not the first, to address those subject areas associated with industrial wiring, plant maintenance, and tasks normally performed by a seasoned journeyworker in the industrial electrical field. The product is designed to facilitate the progress of a relatively inexperienced electrician or a student in developing the basic skills and knowledges needed.

This instructional resource is competency based and is not geared to a specific grade level. The strength of *Industrial Electricity: In-Plant Distribution* is in its assignment and job sheets. Great care has been taken to create exercises that are applicable in industrial settings.

John Humler
Technical Consultant

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USE OF THIS PUBLICATION

Instructional Units

Industrial Electricity: In-Plant Distribution includes four sections and eleven instructional units. A standard format was established in 1970 for development of instructional materials for all Oklahoma vocational teachers. This format includes eight basic components that form a unit of instruction: performance objectives, suggested activities for the teacher, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to tests and assignment sheets. Depending on the specific objectives, there may or may not be transparency masters, assignment sheets, and job sheets included in the unit of instruction.

All of the unit components "zero in" on measurable and observable learning outcomes. Teachers are encouraged to supplement, personalize, localize, and motivate with these materials in order to develop a complete teaching/learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the teacher will help him or her determine the following

A. Amount of material that can be covered in each class period
B. Skills that must be demonstrated
   1. Supplies and equipment needed
   2. Amount of practice needed
   3. Amount of class time needed for demonstrations
C. Supplementary materials, such as pamphlets and filmstrips, that must be ordered
D. Resource people who must be contacted

Performance Objectives (white pages)

Each unit of instruction is based on the performance needed for successful employment in an occupational area. Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction, and specific objectives, stating the performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching/learning process, it is important that teachers and students have a common understanding of the intent of the objectives. Following is a list of performance terms, their meanings, and behavioral synonyms that may have been used in this material.

A. Name — The individual supplies a name for objects, events, or people

   Behavioral synonyms: Label, list, letter, record, reiterate, repeat, write

B. Identify — The individual selects a named, described, or pictured object by pointing to it, touching it, picking it up, or selecting it

   Behavioral synonyms: Select, mark, match, choose, judge

C. State a rule — The individual communicates a relationship or principle that could be used to solve problems or perform a task

D. Apply a rule — The individual supplies an answer to a problem by using a stated relationship or principle

Behavioral synonyms: Solve, calculate

E. Describe — The individual relates sufficient characteristics or properties of an object or event so that a second individual will be able to state what is being discussed

Behavioral synonyms: Define, discuss, interpret, recite, tell how, tell what happens when

F. Distinguish — The individual selects an object or event from two or more that are easily confused

Behavioral synonyms: Discriminate, differentiate

G. Order — The individual arranges three or more objects or events in a sequence based on a stated property

Behavioral synonyms: Arrange, sequence, list in order, classify, divide, isolate, sort

H. Construct — The individual makes a physical object, a verbal statement, or a drawing

(NOTE: *Construct* is used when the finished product or result is important.)

Behavioral synonyms: Draw, make, build, design, formulate, reproduce, transcribe, convert, put together, compile

I. Demonstrate — The individual performs several operations necessary to carry out a specified process

(NOTE: *Demonstrate* is used when it is desirable to watch the student perform a task, one of the highest levels of student performance.)

Behavioral synonyms: Show your work, show procedure, perform an experiment, perform the steps, operate, remove, replace, turn off/on, (dis)assemble, (dis)connect

The objectives should be provided for students and stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods. Prepare for each unit by deciding how each objective can best be taught.

The objective sheet may also be used as a quick pretest to determine prior knowledge of students and to determine whether further study or activities are necessary. Teachers should feel free to modify, delete, or add objectives in order to meet the needs of the students and community. When changes in objectives are made, the teacher should remember to supply the needed information, assignment and/or job sheets, and criterion test items.

Suggested Activities (pink pages)

This component is included only in teacher material. The suggested activities page assists teachers during the preparation stage of the teaching/learning process by providing suggestions for delivery and/or presentation during the instructional process. Read the suggested activities before teaching the units to allow time to obtain supplemental materials, prepare audiovisual materials, and contact outside resources. Duties of the teacher will vary according to the particular unit.

The references that are listed are ones used in the development of each unit. They should be used by the teacher to supplement her or his knowledge of the subject area or to help students with particular interests or occupational objectives in the area covered.

Information Sheet (green pages)

The information sheet provides "must know" content essential for meeting the cognitive (knowledge level) objectives of the unit. The information is written in a topical outline form and is keyed to the specific objectives.

Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. The information sheet may also be used for coordination activities and advisory committees.

Students should read the information sheet before the information is discussed in class. Space is provided in margins for students and teachers to add notes that supplement, localize, personalize, or provide motivation for each unit.

Transparency Masters (white pages in teacher material and green in student material)

Transparency masters provide information in a special way. Transparencies direct the class's attention to the topic of discussion. Transparencies may present new information, or they may reinforce information presented in the information sheet. They are particularly effective when identification is necessary. Make transparencies and place them in the notebook where they will be immediately available for use.

Assignment Sheets (brown pages)

Assignment sheets give students a chance at problem solving, self-assessment, and/or practical experience with the information. They assist students in the application of knowledges that are necessary prerequisites to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided when appropriate and can be used by the student and/or teacher for checking student progress.

Job Sheets (blue pages)

Job sheets are another important segment of a unit of instruction. The job sheets provide a list of equipment, tools, and materials needed to complete a manipulative or psychomotor skill. They describe a step-by-step procedure needed to complete each task or job. Diagrams, photographs, and illustrations are provided to assist students in achieving the skill.

Instruments in job sheets are not in order of use. This should be taught in the classroom. In this way, students will not depend entirely on job sheets for instrument setup.

A teacher should demonstrate to students the procedures outlined in each job sheet. Furthermore, the teacher needs to localize the job sheet according to the equipment and supplies available in the local lab or shop situation. Job sheets also furnish potential employers with a picture of the skills being taught and the performances they might reasonably expect from a person who has had this vocational instruction.

Tests (yellow pages)

This component provides criterion-referenced evaluation of every objective listed in the unit of instruction. It is crucial to note that both paper/pencil and performance objectives must be evaluated.

The tests may be written or oral. It is recommended that the tests be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of questions from the units covered may be used for final tests at the end of each term if desired. If objectives have been added, deleted, or modified, be sure to make the changes on the test.

The acceptable response on a unit test, 85 percent in most units, may be raised or lowered to fit the topic or students' ability levels. The percentage applies to the overall score, not to each individual question. The final unit grade should be obtained by using the paper/pencil score along with evaluations of student demonstrations of the desired skills.

Answers to Test and Assignment Sheets (pink pages)

These components are designed to assist the teacher in evaluation of student performances.

Page Numbering

Each publication from the Curriculum and Instructional Materials Center is assigned a specific abbreviation. For example, *Industrial Electricity: In-Plant Distribution* has been abbreviated IED. The units are then numbered consecutively within each section. An example of a page number is IED-1-A. Since CIMC publications are loose leaf, this system of page numbering was adopted so that pages from different manuals would not get mixed up.

Methods of Disseminating Material

Material may be given out a unit or page at a time to keep the material before the student always new. Some teachers ask students to furnish a three-ring binder for the units. This is convenient for taking the materials home to study. Upon completion, each unit is then placed in a larger binder. The large binders may be purchased at cost from the CIMC. Some teachers store the materials by units in filing cabinets or boxes until needed. All the units may be given out at once if desired.

For best results, provide student materials for each student. Student materials contain everything but the test answers, answers to assignment sheets, and suggested activities. All tests are collated at the back of student material and should be removed and stored until needed. Students should be allowed to take their materials home at the end of the year.

Teaching Methods

It is a challenge to keep students motivated. Supplement the objectives by providing the "why," personal experiences, and current information. Prepare for each unit by deciding how each objective can best be taught. Allow students to become involved in preparing and planning.

Competency Profiles

Competency profiles are folders used to document student performance. The profile contains a list of the specific job competencies that should be achieved prior to leaving the training program.

CORRECTIONS AND SUGGESTIONS

The Curriculum and Instructional Materials Center wants to provide vocational instructors and students with materials that are accurate and effective. Although the Center strives to maintain the highest standards of development and production, oversights occasionally do occur. If you find any errors in this or other CIMC publications, or have suggestions for improving their usefulness in vocational programs, please notify the CIMC staff. One easy way of pointing out errors is to make a photocopy of the affected page and to indicate the correction on the copy. You can then mail the information to the CIMC, where it will be used to correct the publication before the materials are reprinted.

To ensure that the material is updated on a timely basis, it is important that you notify the Center of necessary corrections as soon as possible after discovering the error. Do not assume that someone else will notice the error and inform the CIMC; other users may be making the same assumption. Please send corrections and recommendations for improving this publication to the following address:

Assistant Coordinator for Development
Curriculum and Instructional Materials Center
Oklahoma State Department of Vocational and
Technical Education
1500 West Seventh Avenue
Stillwater, Oklahoma 74074

USING THE *NATIONAL ELECTRICAL CODE*
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to locate specific wiring and installation information in the *National Electrical Code*. The student will show this knowledge by completing assignment sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct functions abbreviations of standards organizations associated with the *National Electrical Code*.
2. Match terms associated with the *National Electrical Code* to their correct definitions.
3. State the purpose of the *National Electrical Code*.
4. List factors that the *National Electrical Code* is not intended to cover.
5. State the intent of the *National Electrical Code* regarding mandatory enforcement.
6. Match *National Electrical Code* chapter numbers to their correct areas of application.
7. Arrange in order the organizational components of *National Electrical Code* information.
8. Arrange in order the steps for finding information in the *National Electrical Code*.
9. Use the *National Electrical Code* index.
10. Use the *National Electrical Code* introduction and first chapter.
11. Find information in the *National Electrical Code*.

USING THE *NATIONAL ELECTRICAL CODE*
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide each student with a current copy of the *National Electrical Code*.

      (NOTE: The exercises and assignment sheet answers in this manual are based on the 1981 *National Electrical Code*.)

   B. Provide students with objective sheet.

   C. Discuss unit and specific objectives.

   D. Provide students with information and assignment sheets.

   E. Discuss information and assignment sheets.

      1. Discuss abbreviations and standards organizations associated with the *National Electrical Code*, using Information Sheet, Section I. Point out the particular function that each organization serves. Discuss the need for different standards organizations, and explain how these organizations are interrelated with the National Fire Protection Association and the *Code*.

      2. Discuss terms and definitions associated with the *National Electrical Code*, using Information Sheet, Section II. Remind students that the *Code* is the Electrician's "bible." The *Code* sets minimum standards. Electricians must meet these standards; or the inspector will turn them down, job after job.

      3. Discuss the purpose of the *National Electrical Code*, using Information Sheet, Section III. Remind students that the *Code* is a guideline and that the local jurisdiction (such as the inspector or municipality) has the right to make standards *stricter* than those in the *Code*.

      4. Discuss factors that the *National Electrical Code* is not intended to cover, using Information Sheet, Section IV. Remind students that the *National Electrical Code* is set up for minimum safety standards for safeguarding and protecting equipment and personnel. It is not involved in the regulatory process of setting standards for equipment qualifications.

      5. Discuss the intent of the *National Electrical Code* regarding mandatory enforcement, using Information Sheet, Section V. Remind students that the *National Electrical Code* is provided as a guideline for inspectors and municipalities to enforce. It sets the standards, but remember, these are *minimum* standards.

SUGGESTED ACTIVITIES

6. Discuss chapters covering other areas of application in the *National Electrical Code*, using Information Sheet, Section VI. Begin to impress on the students the methodical way the *Code* is laid out. Break down for them, if necessary, the particular areas and divisions of the *Code*.

7. Discuss the arrangement of organizational components of the *National Electrical Code*, using Information Sheet, Section VII. Again, the students should by this time begin to realize that the *Code* is set up in a very logical manner. Impress upon the students the need to be able to locate rapidly and correctly the information they need from the *Code*.

8. Discuss steps for finding information in the *National Electrical Code*, using Information Sheet, Section VIII. At this point, it would be useful to have a local inspector come and discuss the *Code* with your students. This person should discuss the electrician's responsibility to meet *Code* standards and the inspector's responsibility to see that these standards are enforced. Be sure to remind the students that the inspector is not their enemy, but simply a person who is there to protect them and their customers from liability.

9. Explain the *National Electrical Code* index, using Assignment Sheet #1.

10. Explain the *National Electrical Code* introduction and first chapter, using Assignment Sheet #2. Remind the students that the introduction is an overview of the *Code* and that the first chapter provides much information, such as terms and definitions, that are used in the *Code* and on a daily basis in the trade.

11. Discuss again the importance of efficiently finding information in the *National Electrical Code*. Use Assignment Sheet #3 as appropriate practice for the students.

F. Give test.

G. Reteach and retest if necessary.

II. Instructional materials

  A. Objective sheet

  B. Suggested activities

  C. Information sheet

  D. Assignment sheets

    1. Assignment Sheet #1 — Use the *National Electrical Code* Index

SUGGESTED ACTIVITIES

   2. Assignment Sheet #2 — Use the *National Electrical Code* Introduction and First Chapter

   3. Assignment Sheet #3 — Find Information in the *National Electrical Code*

  E. Answers to assignment sheets

  F. Test

  G. Answers to test

III. Unit references

  A. *National Electrical Code 1981.* Boston: National Fire Protection Association, 1980.

  B. Ross, Joseph A., ed., and Wilford I. Summers, technical consultant. *The National Electrical Code Handbook,* 2nd ed. Quincy, Massachusetts: National Fire Protection Association, 1981.

USING THE *NATIONAL ELECTRICAL CODE*
UNIT I

INFORMATION SHEET

I. Abbreviations and functions of standards organizations

   A. ANSI (American National Standards Institute) — Develops standards for electrical equipment and supplies

   B. ASA (American Standards Association) — Develops standards for electrical machinery and equipment

   C. NEMA (National Electrical Manufacturers Association) — Develops electrical equipment standards

   D. NFPA (National Fire Protection Association) — Develops and publishes fire and industrial safety standards

   E. UL (Underwriters Laboratories) — Tests equipment and lists it for use in specified situations

II. Terms and definitions

   A. Bonding — Permanent joining of metallic parts to form an electrically conductive path that will ensure electrical continuity and the capacity to conduct safely any current likely to be imposed

   B. Bonding jumpers — Pieces of wire or other conductors that connect different metal parts

   C. Bonding jumper circuit — Connection between portions of a conductor in a circuit to maintain required ampacity of the circuit

   D. Bonding jumper equipment — Connection between two or more portions of the equipment grounding conductor

   E. Building code — Standards developed to provide for safe building construction practices

   F. Grounded — Connected to earth or to some conducting body that serves in place of the earth

   G. Grounded conductor — Intentionally grounded system or circuit conductor

   H. Grounding conductor — Conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or electrodes

INFORMATION SHEET

- I. Grounding electrode conductor — Conductor used to connect the grounding electrode to the equipment grounding conductor or to the grounded conductor of the circuit at the service equipment or at the source of a separately derived system
- J. Jurisdiction — Power, right, or authority to interpret the law (code)
- K. Mandatory enforcement — Governmental authority to demand compliance with the *National Electrical Code* requirements for electrical installations
- L. *National Electrical Code* (*NEC*) — Book containing electrical specifications endorsed by NFPA and ANSI; used for legal and regulatory purposes in the interest of life and property protection

III. Purpose of the *National Electrical Code* — Safeguarding persons and property from hazards arising from the use of electricity

IV. Factors the *National Electrical Code* is not intended to cover

- A. Efficiency
- B. Convenience
- C. Good service
- D. Future expansion of electrical use

V. Intent of the *National Electrical Code* regarding mandatory enforcement — The code is intended to be suitable for mandatory enforcement by the governmental authority having jurisdiction

(NOTE: The legal inspector may grant exceptions [special permission] to code requirements, *provided* safety standards are maintained.)

VI. *National Electrical Code* chapter numbers and their areas of application

- A. Chapters 1 through 4 — General application
- B. Chapter 5 — Hazardous locations
- C. Chapter 6 — Special equipment
- D. Chapter 7 — Special conditions
- E. Chapter 8 — Communications systems
- F. Chapter 9 — Tables and examples

INFORMATION SHEET

VII. Sequence of organizational components of *National Electrical Code* information

A. Chapter — Covers broad area of code

B. Article — Covers a specific part of the chapter

C. Parts — Cover a specific item of the article

D. Numbered paragraphs — Cover a specific item of the part

E. Numbered (1) or lowercase lettered (a) subparagraphs

EXAMPLE: Chapter 2 — Wiring Design and Protection
Article 210 — Branch Circuits
Part B — Branch-Circuit Ratings
Paragraph 19 — Conductors — Minimum Ampacity and Size
Subparagraph (b) — Household Ranges and Cooking Appliances

VIII. Steps for finding information in the *National Electrical Code* (Assignment Sheets #1-#3)

(NOTE: The examples following the steps concern the proper method of grounding a service entrance panel.)

A. Refer to index for appropriate area of code

EXAMPLE: Service-entrance equipment

B. Locate specific area in question

EXAMPLE: Grounding of services

C. Turn to article and section as designated

EXAMPLE: Service Equipment — Guarding and Grounding — 230-G
Grounding and Bonding — 230-63
Multiple Circuit Connections — 250-62

D. Read all related areas and exceptions

INFORMATION SHEET

E. Cross-reference if code refers to another article

EXAMPLE:

Service-Entrance Equipment (Disconnecting Means and Overcurrent Protection)

- Definition, Art. 100
- Disconnecting Means, 230-H
  - Approved Type, 230-70
  - Connections ahead of, 230-82
  - Connections to Terminals, 230-81
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  - Electrically Operated, 230-94 Ex. 6
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USING THE *NATIONAL ELECTRICAL CODE*
UNIT I

ASSIGNMENT SHEET #1 — USE THE *NATIONAL ELECTRICAL CODE* INDEX

NAME ______________________________ SCORE ______________

The electrician must be able to use the *Code* in order to answer questions on proper wiring procedures.

Use the *National Electrical Code* index to answer the following questions. Write the correct answers in the blanks.

A. What article covers aircraft hangers?

Article ____________

B. What section covers bonding jumpers?

Code section ____________

C. What section covers boxes over 600 volts?

Code section ____________

D. What section covers support of busways?

Code section ____________

E. What section covers light fixtures in clothes closets?

Code section ____________

F. What section covers the clearances of recessed lighting fixtures?

Code section ____________

G. What section covers overload protection in panelboards?

Code section ____________

H. What section covers appliance accessibility in recreational vehicles?

Code section ____________

I. What section covers construction specifications for rheostats?

Code section ____________

J. What sections cover guarding and grounding on x-ray equipment?

Code sections ____________ and ____________

USING THE *NATIONAL ELECTRICAL CODE*
UNIT I

ASSIGNMENT SHEET #2 — USE THE *NATIONAL ELECTRICAL CODE* INTRODUCTION AND FIRST CHAPTER

NAME ______________________________ SCORE ______________

Find the following information, using the *National Electrical Code* table of contents, introduction, and first chapter. Indicate the code section number(s) that apply to each statement.

A. The purpose of this code is the practical ______________ of persons and property from hazards arising from the use of electricity.

Code section __________

B. Tables and examples are found in __________ __________

C. Define the following terms. *Code* section __________

1. Ampacity — ______________________________

____

____

2. Branch circuit — ______________________________

____

____

3. Outlet — ______________________________

____

____

4. Service cable — ______________________________

____

____

5. Bonding — ______________________________

____

____

6. Covered conductor — ______________________________

____

____

ASSIGNMENT SHEET #2

7. Receptacle — ____

____

____

8. Service drop — ____

____

____

9. Device — ____

____

____

10. Disconnecting means — ____

____

____

11. Equipment — ____

____

____

12. Overload — ____

____

____

13. Service lateral — ____

____

____

14. Thermally protected — ____

____

____

ASSIGNMENT SHEET #2

15. Weatherproof — ______________________________

____

____

16. Ventilated — ______________________________

____

____

17. Thermal cutout — ______________________________

____

____

18. Service raceway — ______________________________

____

____

19. Readily accessible — ______________________________

____

____

20. Enclosed — ______________________________

____

____

USING THE *NATIONAL ELECTRICAL CODE*
UNIT I

ASSIGNMENT SHEET #3 — FIND INFORMATION IN THE *NATIONAL ELECTRICAL CODE*

NAME ______________________________ SCORE ______________

PART I

Use the *National Electrical Code*, Article 250, parts to find the following information. Write the correct answers in the appropriate blanks.

A. Article 250-1 covers general and specific requirements for grounding and bonding of electrical installation.

List the six specific requirements detailed in the *Code*.

Article part ____________ *Code* section ____________

1. ____

____

2. ____

____

3. ____

____

4. ____

____

5. ____

____

6. ____

____

B. Portable generators (in some instances) are not required to be grounded to earth.

Article part ____________ *Code* section ____________

True ____________ False ____________

ASSIGNMENT SHEET #3

C. In grounding separately derived AC systems, "the grounding electrode shall be as near as practicable to and preferably in the same area as the grounding conductor connection to the system."

Article part __________ *Code* section __________

True __________ False __________

D. "Bonding shall be ________________ where necessary to assure electrical continuity and the capacity to conduct safely any __________ __________ likely to be imposed."

Article part __________ *Code* section __________

E. "The metal covering of service cable having an ________________ grounded service conductor in continuous electrical contact with its metallic armor or tape shall be considered to be grounded."

Article part __________ *Code* section __________

F. "An equipment bonding ________________ shall be used to connect the grounding terminal of a grounding-type receptacle to a grounded box." How many exceptions are there? ________________

Article part __________ *Code* section __________

G. "Main and equipment bonding jumpers shall be of __________ or other corrosion-resistant material."

Article part __________ *Code* section __________

H. "The size of copper, aluminum, or copper-clad aluminum equipment grounding conductors shall not be less than given in Table 250-95." Give the sizes of copper equipment grounding conductors for 100-ampere, 200-ampere, and 400-ampere circuits.

Article part __________ *Code* section __________

100 A = __________

200 A = __________

400 A = __________

I. "____________ or ____________ of instrument transformers shall be grounded where accessible to other than qualified persons."

Article part __________ *Code* section __________

ASSIGNMENT SHEET #3

J. In making grounding conductor connections, "required grounding conductors and bonding jumpers shall be connected by pressure connectors, clamps, or other approved means. Connection devices or fittings that depend on solder shall ______________ be used."

Article part ____________ *Code* section ____________

PART II

Use the *National Electrical Code,* Articles 336 through 364, to find the following information. Write the correct answers in the appropriate blanks.

A. Type NM cable shall not be run in a shallow chase in masonry walls.

True ____________ False ____________ *Code* section ____________

B. Protective guard strips are required for Romex and NM cable within 7 feet of the nearest edge of an accessible attic entrance; however, where the space is not accessible by permanent stairs or ladders, the guard strips shall be within ____________ feet of the attic entrance.

Code section ____________

C. Intermediate metal conduit is not acceptable as an equipment grounding conductor.

True ____________ False ____________ *Code* section ____________

D. Aluminum fittings and enclosures are permitted on steel rigid metallic conduit runs.

True ____________ False ____________ *Code* section ____________

E. Rigid metallic conduit threads are to be tapered at ³/₄ inch per foot.

True ____________ False ____________ *Code* section ____________

F. Rigid nonmetallic conduit sizes ¹/₂ inch to 1 inch are to be supported at 3-foot intervals.

True ____________ False ____________ *Code* section ____________

G. Electrical metallic tubing (EMT) conduit shall not be threaded.

True ____________ False ____________ *Code* section ____________

H. Flexible metallic tubing runs shall not be over 6 feet.

True ____________ False ____________ *Code* section ____________

ASSIGNMENT SHEET #3

I. Three-eighths-inch flexible metal conduit runs are limited to 6 feet in length.

True ____________ False ____________ *Code* section ____________

J. A busway is considered to be a grounded metal enclosure containing factory-mounted, bare or insulated conductors.

True ____________ False ____________ *Code* section ____________

PART III

Use the *National Electrical Code*, Articles 430 through 501, to find the following information. Write the correct answers in the appropriate blanks.

A. In marking motors, the nameplate is to show both voltage and full-load current; for multispeed motors, the nameplate is to show full-load amperage for each speed.

True ____________ False ____________ *Code* section ____________

B. The circuit of a control apparatus that carries the electric signals directing the performance of the controller, but does not carry the main power current, is called ________

____________ ____________

Code section ____________

C. The disconnecting means for a torque motor shall have an ampere rating of 125 percent of the motor nameplate current.

True ____________ False ____________ *Code* section ____________

D. The branch circuit for an air conditioner compressor unit may have a short circuit protection device rated at 225 percent of the motor-rated load.

True ____________ False ____________ *Code* section ____________

E. The ampacity of generator phase wires to the first overcurrent device shall not be less than 125 percent of the nameplate current rating.

True ____________ False ____________ *Code* section ____________

F. Water pipes intended for vault fire protection or transformer cooling are permitted in a transformer vault.

True ____________ False ____________ *Code* section ____________

G. In general, a capacitor to correct the power factor of a motor circuit shall not exceed that capacity needed to produce a power factor of unity.

True ____________ False ____________ *Code* section ____________

ASSIGNMENT SHEET #3

H. A sealed cell or battery may have a vent opening but no opening to add battery fluid.

True ____________ False ____________ *Code* section ____________

I. Class 1 hazardous locations are those having to do with hazardous gases or vapors.

True ____________ False ____________ *Code* section ____________

J. Conduit seals in Class 1, Division 1, hazardous locations may be 24 inches from an enclosure for switching.

True ____________ False ____________ *Code* section ____________

PART IV

Use the *National Electrical Code* to find the following information. Answers may be found throughout the *Code*.

A. Generally, service entrance conductors shall not be spliced. How many exceptions to this rule are permitted?

Number ____________ *Code* section ____________

B. A #18 fixture wire is considered to be protected by a 20-ampere breaker.

True ____________ False ____________ *Code* section ____________

C. "Three-way and four-way switches shall be so wired that all switching is done only in the ungrounded circuit conductor. Where in metal enclosures, wiring between switches and outlets shall be run with ____________ ____________________ in the same enclosure."

Code section ____________

D. "Conduit bodies having provisions for less than three conduit entries shall not contain splices, taps, or devices unless they comply with the provisions of *Code* section 370-6(b) and are supported in a rigid and secure manner."

True ____________ False ____________ *Code* section ____________

E. "In completed installations each outlet box shall have a cover, ________________, or fixture canopy."

Code section ____________

F. "The allowable ampacities in Tables 310-16 through 310-19 are based on temperature alone and do not take voltage drop into consideration."

True ____________ False ____________ *Code* section ____________

ASSIGNMENT SHEET #3

G. Where type NM cable (Romex) is installed in accessible attics, "the installation of cable in accessible attics or roof spaces shall comply with *Code* section ____________."

Code section ____________

H. Capacitors 600 volts nominal and under shall be provided with a means of draining the stored charge to 50 volts or less within ____________ ____________________ after being disconnected from power source.

Code section ____________

I. Hazardous locations Class II are those that are hazardous because of the presence of combustible dust.

True ____________ False ____________ *Code* section ____________

J. "All 120-volt receptacles located within 15 feet of the inside walls of a swimming pool shall be protected by a ground-fault circuit-interrupter."

True ____________ False ____________ *Code* section ____________

USING THE *NATIONAL ELECTRICAL CODE*
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 513

B. 250-79

C. 370-D

D. 364-5

E. 410-8

F. 410-66

G. 384-16

H. 551-24

I. 430-82(c)

J. 517-151, 660-D

Assignment Sheet #2

A. Safeguarding; *Code* section 90-1(a)

B. Chapter 9

C. *Code* section 100-A

1. "Current-carrying capacity of electric conductors expressed in amperes"
2. "The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s)"
3. "A point on the wiring system at which current is taken to supply utilization equipment"
4. "Service conductors made up in the form of a cable"
5. "The permanent joining of metallic parts to form an electrically conductive path which will assure electrical continuity and the capacity to conduct safely any current likely to be imposed"

ANSWERS TO ASSIGNMENT SHEETS

6. "A conductor encased within material of composition or thickness that is not recognized by this Code as electrical insulation"

7. "A contact device installed at the outlet for the connection of a single attachment plug"

8. "The overhead service conductors from the last pole or other aerial support to and including the splices, if any, connecting to the service-entrance conductors at the building or other structure"

9. "A unit of an electrical system which is intended to carry but not utilize electric energy"

10. "A device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply"

11. "A general term including material, fittings, devices, appliances, fixtures, apparatus, and the like used as a part of, or in connection with, an electrical installation"

12. "Operation of equipment in excess of normal, full-load rating, or of a conductor in excess of rated ampacity which, when it persists for a sufficient length of time, would cause damage or dangerous overheating. A fault, such as a short circuit or ground fault, is not an overload"

13. "The underground service conductors between the street main, including any risers at a pole or other structure or from transformers, and the first point of connection to the service-entrance conductors in a terminal box or meter or other enclosure with adequate space, inside or outside the building wall. Where there is no terminal box, meter, or other enclosure with adequate space, the point of connection shall be considered to be the point of entrance of the service conductors into the building"

14. "The words 'thermally protected' appearing on the nameplate of a motor or motor-compressor indicate that the motor is provided with a thermal protector"

15. "So constructed or protected that exposure to the weather will not interfere with successful operation"

16. "Provided with a means to permit circulation of air sufficient to remove an excess of heat, fumes, or vapors"

17. "An overcurrent protective device that contains a heater element in addition to and affecting a renewable fusible member which opens the circuit. It is not designed to interrupt short-circuit currents"

18. "The raceway that encloses the service-entrance conductors"

ANSWERS TO ASSIGNMENT SHEETS

19. "Capable of being reached quickly for operation, renewal, or inspections, without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc."

20. "Surrounded by a case, housing, fence, or walls which will prevent persons from accidentally contacting energized parts"

Assignment Sheet #3

PART I

A. Article part A, *Code* section 250-1

   1. "Systems, circuits, and equipment required, permitted, or not permitted to be grounded"

   2. "Circuit conductor to be grounded on grounded systems"

   3. "Location of grounding connections"

   4. "Types and sizes of grounding and bonding conductors and electrodes"

   5. "Methods of grounding and bonding"

   6. "Conditions under which guards, isolation, or insulation may be substituted for grounding"

B. Article part B; *Code* section 250-6(a); True

C. Article part C; *Code* section 250-26(c); True

D. Provided; fault current; Article part G; *Code* section 250-70

E. Uninsulated; Article part G; *Code* section 250-73

F. Jumper; four exceptions; Article part G; *Code* section 250-74

G. Copper; Article part G; *Code* section 250-79(a)

H. Article part J; *Code* section 250-95; #8, #6, #3

I. Cases or frames; Article part L; *Code* section 250-122

J. Not; Article part K; *Code* section 250-113

ANSWERS TO ASSIGNMENT SHEETS

PART II

A. True; *Code* section 336-3(a)

B. 6 feet; *Code* section 336-9, ref. to 333-12(a)

C. False; *Code* section 345-3(a), ref. to 250-91(b)

D. True; *Code* section 346-1(b) exception

E. True; *Code* section 346-7(b)

F. True; *Code* section 347-8, table

G. True; *Code* section 348-7

H. True; *Code* section 349-4

I. True; *Code* section 350-3, exception #3

J. True; *Code* section 364-2

PART III

A. True; *Code* section 430-7(a)(2)

B. Motor control circuit; *Code* section 430-71

C. False; *Code* section 430-110(b)

D. True; *Code* section 440-22(a)

E. False; *Code* section 445-5

F. True; *Code* section 450-47

G. False; *Code* section 460-8(a)

H. True; *Code* section 480-2

I. True; *Code* section 500-4

J. False; *Code* section 501-5(a)(1)

ANSWERS TO ASSIGNMENT SHEETS

PART IV

A. Five; *Code* section 230-46

B. True; *Code* section 240-4

C. Both polarities; *Code* section 380-2(a)

D. True; *Code* section 370-6(c)

E. Faceplate; *Code* section 370-15

F. True; Note 12 to tables 310-16 through 310-19

G. 333-12; *Code* section 336-9

H. One minute; *Code* section 460-6(a)

I. True; *Code* section 500-5

J. True; *Code* section 680-6(a)(3)

USING THE *NATIONAL ELECTRICAL CODE*
UNIT I

TEST

NAME ______________________________ SCORE ______________

1. Match to their correct functions abbreviations of standards organizations associated with the *National Electrical Code*. Write the correct numbers in the blanks.

_____a. Develops electrical equipment standards

_____b. Develops standards for electrical machinery and equipment

_____c. Develops and publishes fire and industrial safety standards

_____d. Develops standards for electrical equipment and supplies

_____e. Tests equipment and lists it for use in specified situations

1. NFPA (National Fire Protection Association)
2. NEMA (National Electrical Manufacturers Association)
3. UL (Underwriters Laboratories)
4. ANSI (American National Standards Institute)
5. ASA (American Standards Association)

2. Match terms associated with the *National Electrical Code* to their correct definitions. Write the correct numbers in the blanks. Terms and definitions are continued on the next page.

_____a. Standards developed to provide for safe building construction practices

_____b. Intentionally grounded system or circuit conductor

_____c. Book containing electrical specifications endorsed by NFPA and ANSI; used for legal and regulatory purposes in the interest of life and property protection

_____d. Permanent joining of metallic parts to form an electrically conductive path that will ensure electrical continuity and the capacity to conduct safely any current likely to be imposed

1. *National Electrical Code* (NEC)
2. Building code
3. Grounded conductor
4. Bonding

TEST

_____e. Conductor used to connect the grounding electrode to the equipment grounding conductor or to the grounded conductor of the circuit at the service equipment or at the source of a separately derived system

_____f. Connection between two or more portions of the equipment grounding conductor

_____g. Power, right, or authority to interpret the law (code)

_____h. Connection between portions of a conductor in a circuit to maintain required ampacity of the circuit

_____i. Governmental authority to demand compliance with the *National Electrical Code* requirements for electrical installations

_____j. Conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or electrodes

_____k. Pieces of wire or other conductors that connect different metal parts

_____l. Connected to earth or to some conducting body that serves in place of the earth

5. Bonding jumper equipment
6. Grounding electrode conductor
7. Bonding jumpers
8. Grounded
9. Mandatory enforcement
10. Grounding conductor
11. Jurisdiction
12. Bonding jumper circuit

3. State the purpose of the *National Electrical Code*.

4. List factors that the *National Electrical Code* is not intended to cover.

a. ______

b. ______

c. ______

d. ______

TEST

5. State the intent of the *National Electrical Code* regarding mandatory enforcement.

____

____

____

6. Match *National Electrical Code* chapter numbers to their correct areas of application. Write the correct numbers in the blanks.

_____a. Communications systems

_____b. Special equipment

_____c. General application

_____d. Tables and examples

_____e. Special conditions

_____f. Hazardous locations

1. Chapters 1 through 4
2. Chapter 5
3. Chapter 6
4. Chapter 7
5. Chapter 8
6. Chapter 9

7. Arrange in order the organizational components of *National Electrical Code* information. Write a "1" before the first step, a "2" before the second step, and so on.

_____a. Numbered paragraphs

_____b. Article

_____c. Chapter

_____d. Parts

_____e. Numbered or lowercase lettered subparagraphs

8. Arrange in order the steps for finding information in the *National Electrical Code*. Write a "1" before the first step, a "2" before the second step, and so on.

_____a. Turn to article and section as designated

_____b. Read all related areas and exceptions

_____c. Refer to index for appropriate area of code

_____d. Cross-reference if code refers to another article

_____e. Locate specific area in question

TEST

(NOTE: Test questions 9-11 list the assignment sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

9. Use the *National Electrical Code* index.
10. Use the *National Electrical Code* introduction and first chapter.
11. Find information in the *National Electrical Code*.

USING THE *NATIONAL ELECTRICAL CODE*
UNIT I

ANSWERS TO TEST

1.	a.	2	d.	4		
	b.	5	e.	3		
	c.	1				

2.	a.	2	e.	6	i.	9
	b.	3	f.	5	j.	10
	c.	1	g.	11	k.	7
	d.	4	h.	12	l.	8

3. Safeguarding persons and property from hazards arising from the use of electricity

4. a. Efficiency
   b. Convenience
   c. Good service
   d. Future expansion of electrical use

5. The code is intended to be suitable for mandatory enforcement by the governmental authority having jurisdiction

6.	a.	5	d.	6
	b.	3	e.	4
	c.	1	f.	2

7.	a.	4	d.	3
	b.	2	e.	5
	c.	1		

ANSWERS TO TEST

8. a. 3
   b. 4
   c. 1
   d. 5
   e. 2

9. Evaluated to the satisfaction of the instructor

10. Evaluated to the satisfaction of the instructor

11. Evaluated to the satisfaction of the instructor

POWER EQUIPMENT
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to identify and use common power equipment found in the electrical industry. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with power equipment.
2. List typical electrical power equipment.
3. State general safety rules for using power equipment.
4. Label the parts of a hydraulic knockout set.
5. State specific safety rules for using hydraulic knockout sets.
6. Label the parts of a hydraulic pipe bender.
7. State specific safety rules for using hydraulic pipe benders.
8. Label the parts of an electric polyvinyl chloride (PVC) heater.
9. State specific safety rules for using electric polyvinyl chloride (PVC) heaters.
10. Label the parts of a power drill.
11. State specific safety rules for using power drills.
12. Label the parts of a power threader.
13. Identify power threader accessories.
14. State specific safety rules for using power threaders.
15. Demonstrate the ability to
    a. Use a hydraulic knockout punch.
    b. Bend a 90-degree stub, using a hydraulic pipe bender.
    c. Make offset and 90-degree bends, using an electric PVC heater.
    d. Cut, ream, and thread steel pipe with a power threader.

POWER EQUIPMENT
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

A. Gather equipment and materials for job sheet demonstrations.

B. Take students on a field trip to a local electrical supply shop so that they may see examples of the power equipment and accessories discussed in this unit.

C. Make transparencies.

D. Provide students with objective sheet.

E. Discuss unit and specific objectives.

F. Provide students with information and job sheets.

G. Discuss information sheet.

1. Discuss terms and definitions, using Information Sheet, Section I. Show students examples of tools defined.

2. Discuss typical electrical power equipment, using Information Sheet, Section II. Discuss the uses of each piece of equipment, and explain how each aids the electrician.

3. Discuss general safety rules for using power equipment, using Information Sheet, Section III. Remind students that power equipment normally has high temperature and parts and fluids under extreme pressures, which can cause damage to hands, fingers, or eyes should the equipment be used improperly.

4. Discuss parts of the hydraulic knockout set, using Information Sheet, Section IV, Transparency #1, and Job Sheet #1. Have available a knockout set so that its parts may be matched with the transparency, and the proper assembly of the pump hoses and knockout die and cutter can be shown.

5. Discuss specific safety rules for using the hydraulic knockout set, using Information Sheet, Section V. Stress that this particular device not only has high hydraulic pressure, but also has mechanical devices under extreme pressure. Supervise closely the activities in Job Sheet #1.

SUGGESTED ACTIVITIES

6. Discuss the parts of a hydraulic pipe bender, using Information Sheet, Section VI, Transparency #2, and Job Sheet #2. Have available an actual bender so that students can see its parts, the ram travel gauge, and the way that it is assembled.

7. Discuss specific safety rules for using hydraulic pipe benders, using Information Sheet, Section VII. Again, stress to students that they will be working with hydraulic fluids under extreme pressures. Show students the pinch points in the pipe bender, and caution students against getting a finger or hand caught in one of these pinch points, which exerts several thousand pounds of pressure. Warn that such pressure can permanently damage or actually sever a finger or hand from the body. Supervise closely the activities in Job Sheet #2.

8. Discuss the parts of an electric PVC heater, using Information Sheet, Section VIII, Transparency #3, and Job Sheet #3. Have available a PVC heater so that students can examine the heating chamber and notice the closeness of the heating element to the pipe. Stress the need to take extra precautions not to be burned by hot pipe or to scorch the pipe.

9. Discuss specific safety rules for using electric PVC heaters, using Information Sheet, Section IX. Impress upon the students that the intense heat used to cause the pipe to soften presents a burn hazard, and that gloves should always be used when handling hot PVC pipe. Also point out that water is frequently used to cool the pipe after it has been heated, and that the water, combined with the electricity being used for the heater element, presents a shock hazard. Stress that care should be taken not to allow water on or near the PVC bender. Supervise closely the activities in Job Sheet #3.

10. Discuss the parts of power drills, using Information Sheet, Section X and Transparency #4. Have a power drill available to show the students the proper installation of the cross handle for high-torque applications.

11. Discuss specific safety rules for using the power drill, using Information Sheet, Section XI. Show students that the hold button or hold trigger button can be easily pressed by accident under normal right-handed use, thus making it possible to release the trigger but have the drill continue to run. Caution students to take care not to accidently press the hold button, because should the drill then bind, the user would not be able to release the drill immediately. Also explain the importance of balance when using a high-torque drill. Without proper balance, the drill user can be thrown off a ladder or twist so that the drill swings around and hits the user's side or arm.

SUGGESTED ACTIVITIES

12. Discuss the parts of power threaders, using Information Sheet, Section XII, Transparency #5, and Job Sheet #4. Have available a power threader so that students can familiarize themselves with its parts. Carefully point out and explain the parts that can endanger students' safety.

13. Discuss power threader accessories, using Information Sheet, Section XIII. Point out similarities and differences, explain uses, and stress safety factors associated with each accessory.

14. Discuss specific safety rules for using power threaders, using Information Sheet, Section XIV. Stress that these tools, as well as the threads created by them, are sharp, and that an extremely high torque is produced by the turning of the pipe chuck. The pipe chuck will continue turning even when a piece of clothing catches on one of its jaws and could pull in an arm or part of the body. The torque produced by the typical power threader is sufficient to break a person's arm or to sever a limb from the body. Carefully supervise the students as they perform the activities in Job Sheet #4. If a student has not been personally supervised and checked out on this piece of equipment, he or she should not be permitted to use it.

H. Demonstrate and discuss procedures outlined in job sheets.

I. Give test.

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Hydraulic Knockout Set

2. TM #2 — Hydraulic Pipe Bender

3. TM #3 — Electric PVC Heater

4. TM #4 — Power Drill

5. TM #5 — Power Threader

SUGGESTED ACTIVITIES

E. Job sheets

1. Job Sheet #1 — Use a Hydraulic Knockout Punch

2. Job Sheet #2 — Bend a 90-Degree Stub, Using a Hydraulic Pipe Bender

3. Job Sheet #3 — Make Offset and 90-Degree Bends, Using an Electric PVC Heater

4. Job Sheet #4 — Cut, Ream, and Thread Steel Pipe with a Power Threader

F. Test

G. Answers to test

III. Unit references

A. *Greenlee 915-PS Hydraulic Power Pump: Operating, Maintenance Instructions and Parts List*, Bulletin IM 807D. Rockford, Illinois: Greenlee Tool Company, 1971.

B. *Greenlee Timesaving Tools for Electricians and Industry*. Rockford, Illinois: Greenlee Tool Company, 1982.

C. *Milwaukee Electric Tools for Contractors and Industry*. Brookfield, Wisconsin: Milwaukee Electric Tool Corporation, 1982.

D. *Operating Instructions, Maintenance, Parts List: No. 883 Lightweight Hydraulic Hand and Power Benders for Bending Pipe and Conduit,* Bulletin IM 688. Rockford, Illinois: Greenlee Tool Company, 1966.

E. *Rigid 300 Power Drive: Operator's Manual and Parts List*. Elyria, Ohio: The Ride Tool Company, n.d.

F. *Techniques of Conduit and Pipe Bending On-the-Job*. Rockford, Illinois: Greenlee Tool Company, 1962.

POWER EQUIPMENT
UNIT II

INFORMATION SHEET

I. Terms and definitions

- A. Bender — Tool used to make various angles or bends in conduit
- B. Chuck — Portion of drill that holds the bit
- C. Cross handle — Handle set across a power tool to prevent the tool from turning
- D. Cutter — Hardened steel device used to cut holes in metal boxes
- E. Die — Component that backs up cutter on opposite side of metal box
- F. Hydraulic — Using pressurized fluid to accomplish work
- G. Hydraulic oil — Specially formulated oil for hydraulic pumps

  (NOTE: No oil or fluid should ever be substituted for hydraulic oil.)
- H. Knockout punch — Device used to make openings for conduit in metal enclosers
- I. Pinch point — Any opening that may close and bind a finger or hand
- J. Polyvinyl chloride (PVC) — Plastic pipe
- K. Ram — Device used to transfer hydraulic pressure to a mechanical device

II. Typical electrical power equipment

- A. Hydraulic knockout
- B. Hydraulic bender
- C. Electric PVC heater
- D. Power drill
- E. Power threader

III. General safety rules for using power equipment

- A. Always follow manufacturer's operating instructions
- B. Never place hands in a pinch point

INFORMATION SHEET

C. Use eye protection when cutting or drilling

D. Wear gloves when working with hot equipment or materials

E. Always secure loose clothing such as shirt sleeves and shirttails

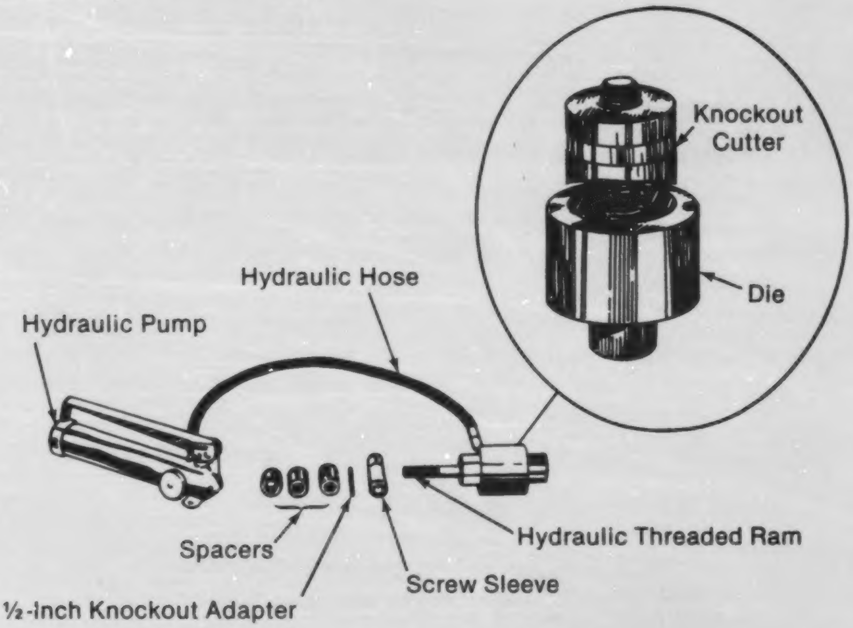
F. Never exceed rated capacity of equipment

G. Never leave running equipment unattended

H. Never remove protective guards from equipment

IV. Parts of a hydraulic knockout set (Figure 1; Transparency #1)

FIGURE 1


Knockout Cutter
Die
Hydraulic Hose
Hydraulic Pump
Hydraulic Threaded Ram
Spacers
Screw Sleeve
½-inch Knockout Adapter

V. Specific safety rules for using hydraulic knockout sets

A. Never substitute brake fluid for hydraulic oil

B. Never disconnect hose when it is under pressure

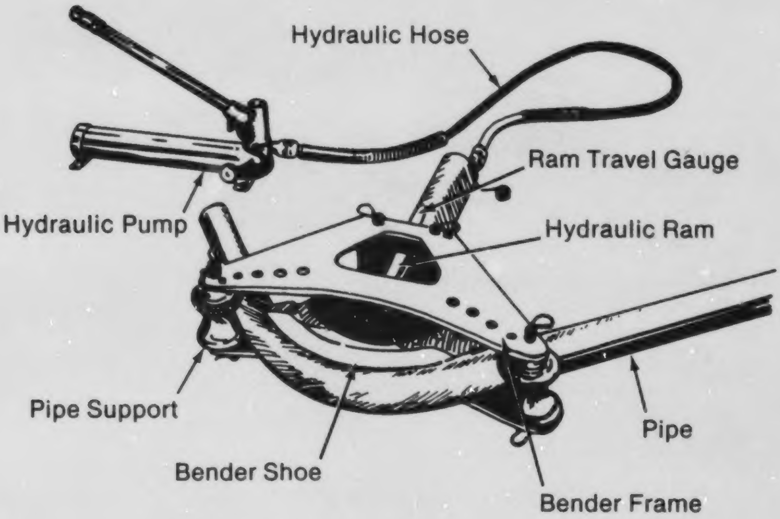
C. Do not use near live electrical parts

D. Never force pump handle

INFORMATION SHEET

VI. Parts of a hydraulic pipe bender (Figure 2; Transparency #2)

FIGURE 2


Hydraulic Hose
Ram Travel Gauge
Hydraulic Pump
Hydraulic Ram
Pipe Support
Pipe
Bender Shoe
Bender Frame

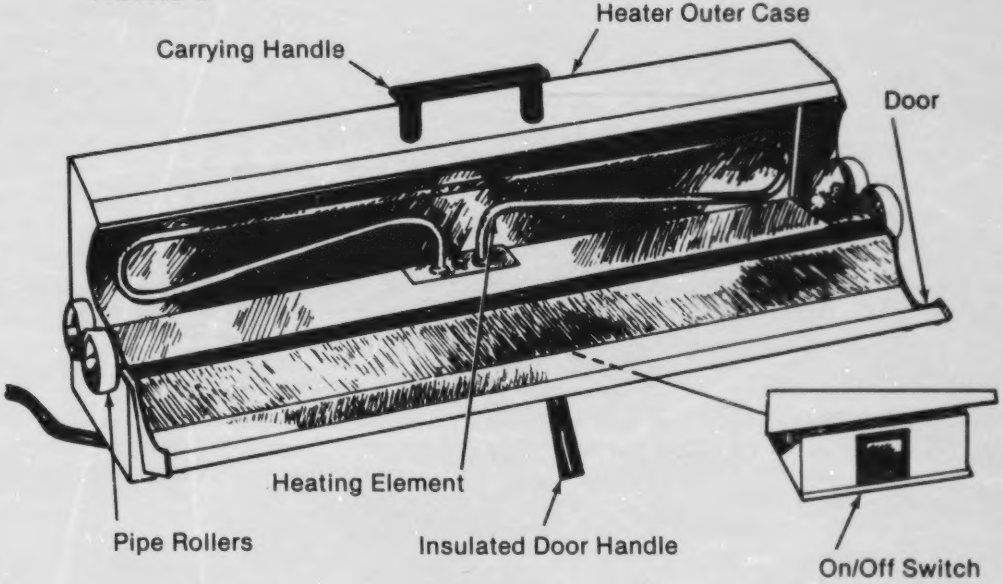
VII. Specific safety rules for using hydraulic pipe benders

- A. Never substitute brake fluid for hydraulic oil
- B. Never disconnect hose when it is under pressure
- C. Never place hands near ram or shoe while bending
- D. Always use proper side of conduit shoe and support
- E. Be sure that floor area is clear for pipe movement

INFORMATION SHEET

VIII. Parts of an electric polyvinyl chloride (PVC) heater (Figure 3; Transparency #3)

FIGURE 3


Heater Outer Case
Carrying Handle
Door
Heating Element
Pipe Rollers
Insulated Door Handle
On/Off Switch

IX. Specific safety rules for using electric polyvinyl chloride (PVC) heaters

A. Never use in wet locations

B. Always wear gloves when handling hot heater or pipe

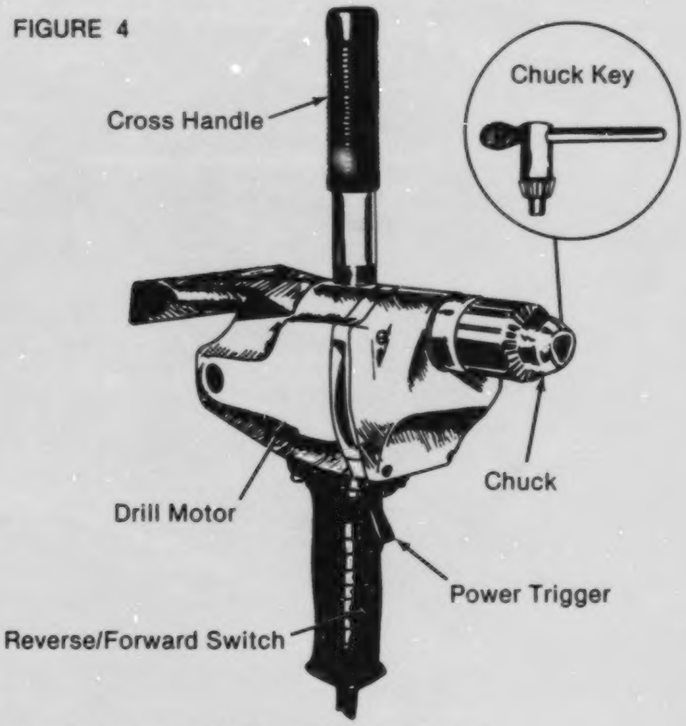
C. Use only with PVC conduit

D. Always turn bender off when not in use

INFORMATION SHEET

X. Parts of a power drill (Figure 4; Transparency #4)

FIGURE 4


Cross Handle
Chuck Key
Chuck
Drill Motor
Power Trigger
Reverse/Forward Switch

XI. Specific safety rules for using power drills

A. Always wear eye protection

B. Check area to be drilled for hidden wires or pipes

C. Hold drill securely with both hands

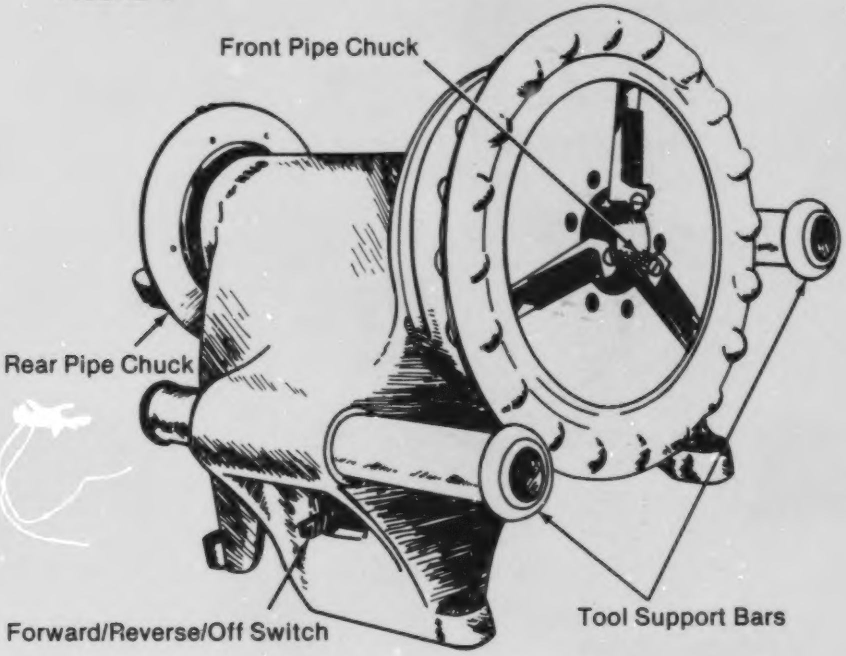
D. Never drill while off balance

E. Place small objects to be drilled in a vise

INFORMATION SHEET

XII. Parts of a power threader (Figure 5; Transparency #5)

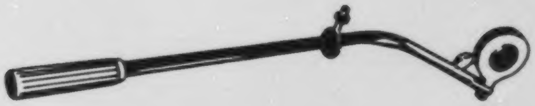
FIGURE 5


Front Pipe Chuck
Rear Pipe Chuck
Forward/Reverse/Off Switch
Tool Support Bars

XIII. Power threader accessories (Figures 6-12)

A. Carriage lever

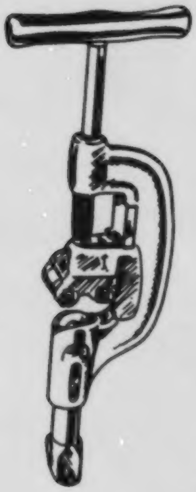
FIGURE 6



INFORMATION SHEET

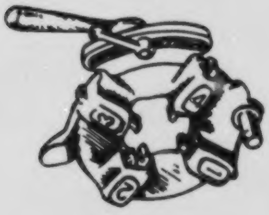
B. Cutter

FIGURE 7



C. Adjustable die head

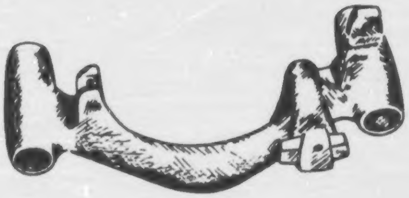
FIGURE 8



INFORMATION SHEET

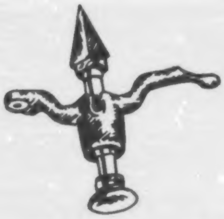
D. Tool carriage

FIGURE 9



E. Reamer

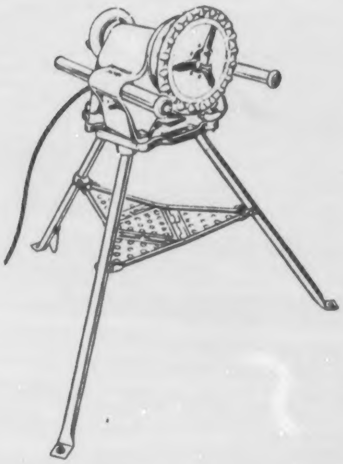
FIGURE 10



INFORMATION SHEET

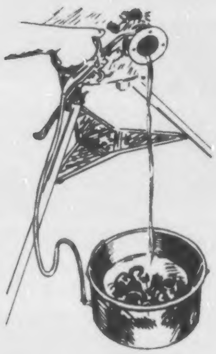
F. Power threader stand

FIGURE 11



G. Oiler

FIGURE 12



INFORMATION SHEET

XIV. Specific safety rules for using power threaders

A. Always wear eye protection

B. Always wear tight-fitting clothing

C. Use gloves when handling pipe

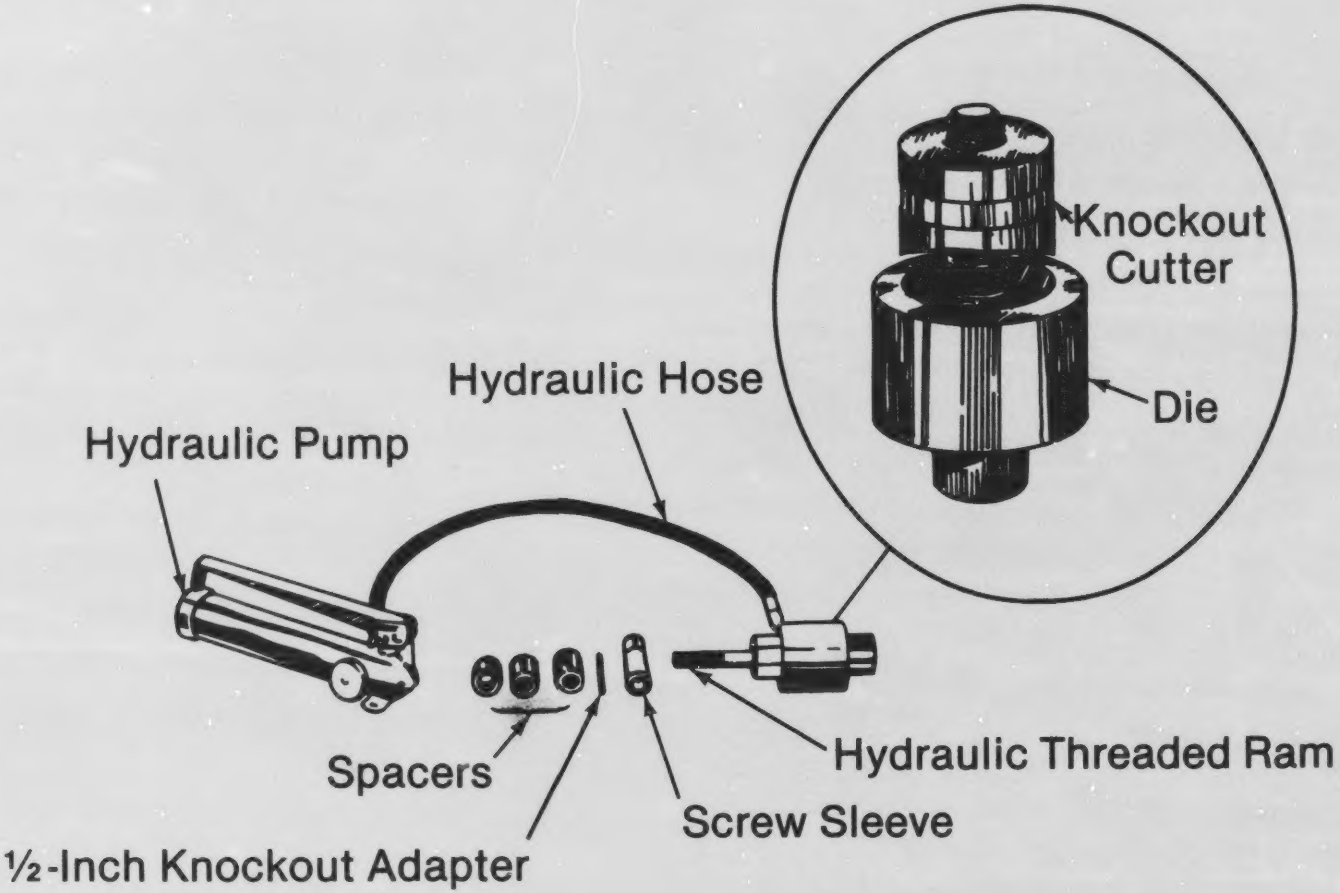
D. Never place hands near turning pipe

E. Let threader come to a complete stop before removing pipe or reversing direction

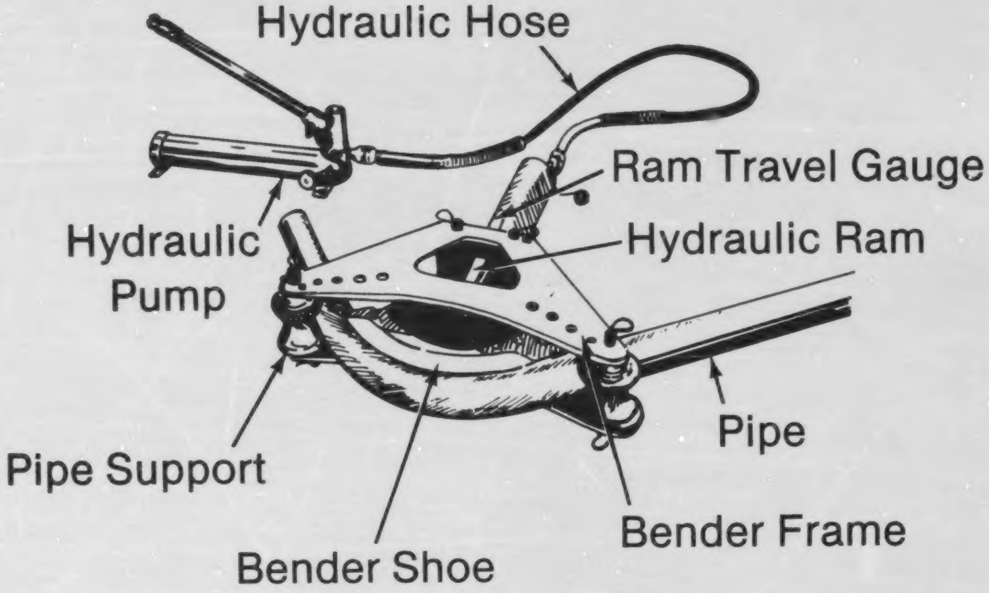
F. Always use a brush to clear thread cuttings

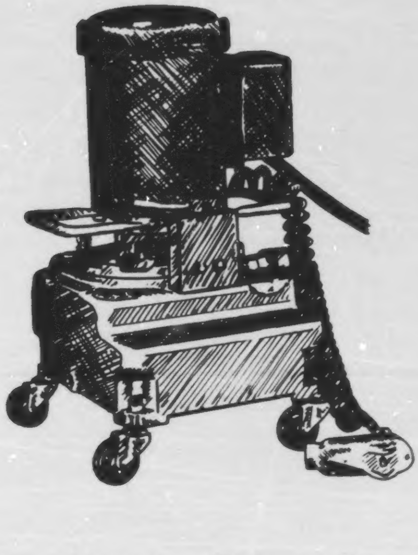
(NOTE: Never use your hands to clear thread cuttings.)

Hydraulic Knockout Set


Knockout Cutter
Die
Hydraulic Hose
Hydraulic Pump
Hydraulic Threaded Ram
Spacers
Screw Sleeve
½-Inch Knockout Adapter

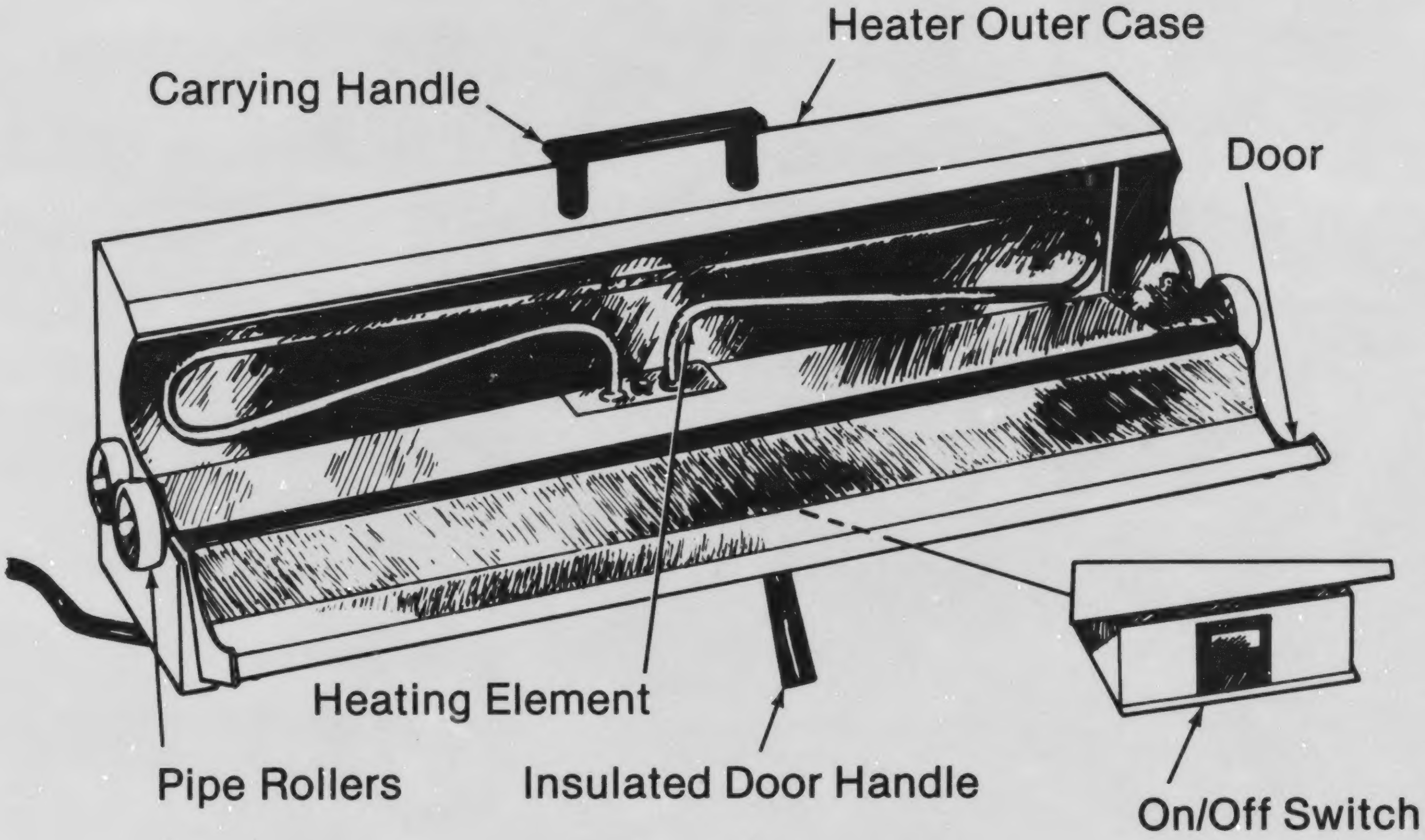
Hydraulic Pipe Bender


Hydraulic Hose
Ram Travel Gauge
Hydraulic Ram
Hydraulic Pump
Pipe
Pipe Support
Bender Frame
Bender Shoe

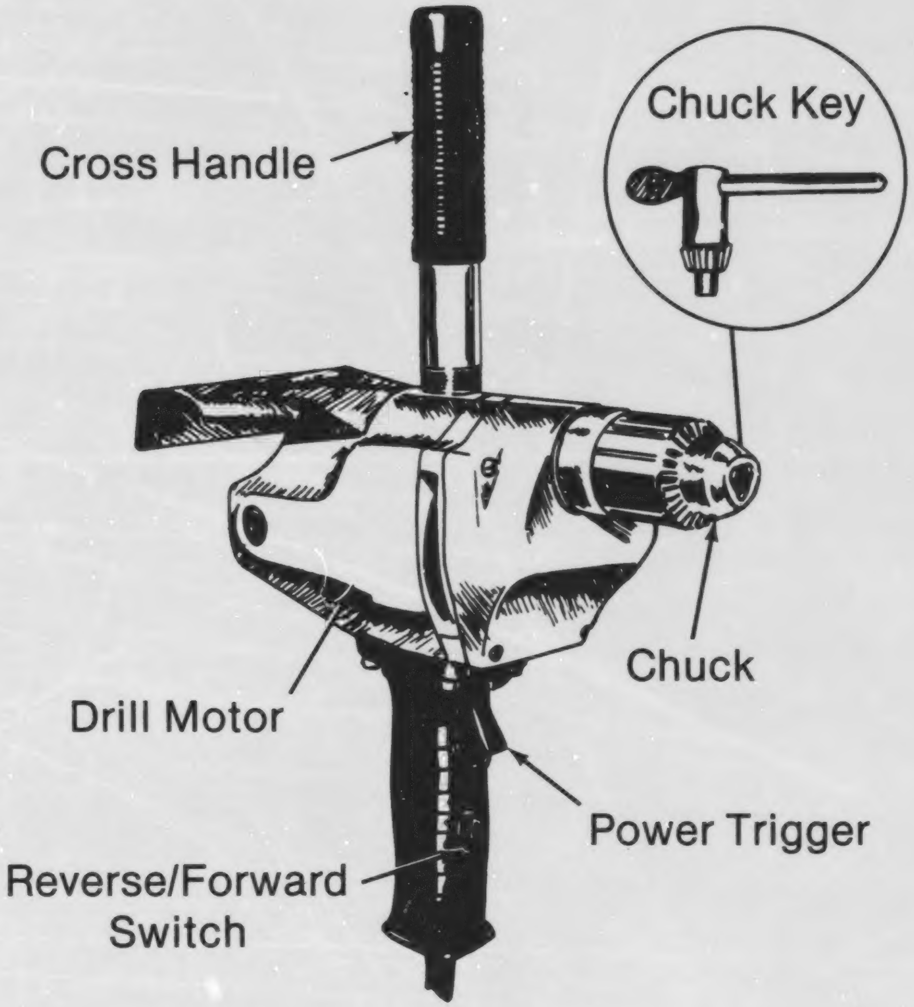


Optional Motor-Driven Pump

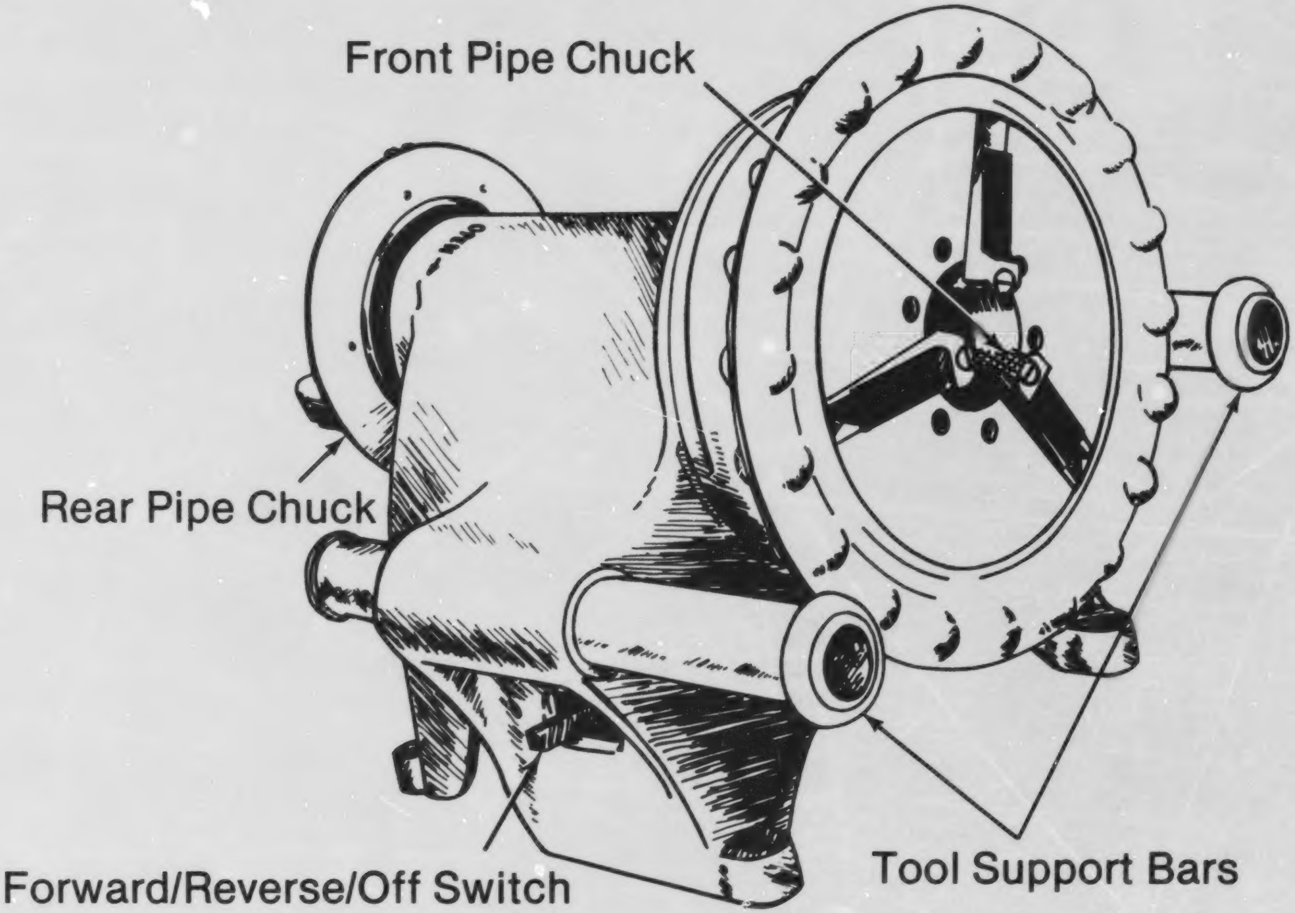
Electric PVC Heater


Heater Outer Case
Carrying Handle
Door
Heating Element
Pipe Rollers
Insulated Door Handle
On/Off Switch

Power Drill


Chuck Key
Cross Handle
Chuck
Drill Motor
Power Trigger
Reverse/Forward Switch

Power Threader


Front Pipe Chuck
Rear Pipe Chuck
Forward/Reverse/Off Switch
Tool Support Bars

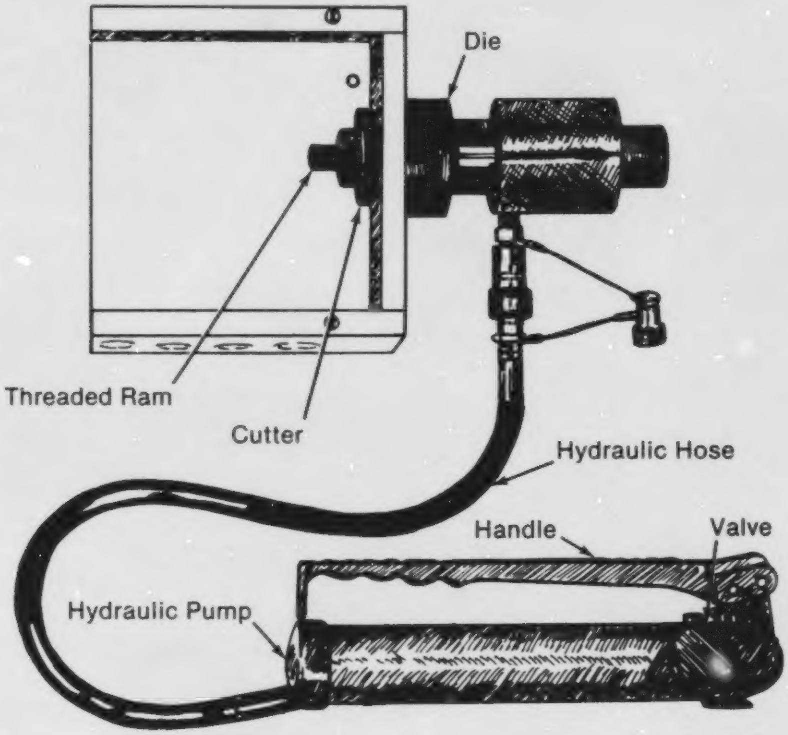
POWER EQUIPMENT
UNIT II

JOB SHEET #1 — USE A HYDRAULIC KNOCKOUT PUNCH

I. Equipment and materials

A. Hydraulic knockout punch with hand pump (Figure 13)

FIGURE 13


Die
Threaded Ram
Cutter
Hydraulic Hose
Handle
Valve
Hydraulic Pump

B. Instructions for knockout punch

C. Drill motor

D. Metal drill bit

(NOTE: The drill bit must be large enough to accept the knockout punch bolt.)

E. Metal to be punched

(NOTE: Most punches are rated up to 10-gauge metal.)

JOB SHEET #1

- F. Vise

  (NOTE: A vise is needed if metal to be cut is not fastened to a wall, or if metal is too small to stand on to hold.)

- G. Eye protection
- H. Heavy-duty extension cord
- I. Center punch
- J. Gloves

II. Procedure

- A. Read instructions for hydraulic knockout set
- B. Assemble hydraulic knockout set, referring to instructions and to Figure 13
- C. Put on eye protection
- D. Fasten metal to be punched in vise if necessary
- E. Put on gloves
- F. Use center punch to make an indentation in the center of the space to be knocked out
- G. Place drill bit on indentation made with center punch, and drill a hole slightly larger than the knockout punch bolt

  (CAUTION: Hold the drill firmly while drilling. A loose grip could cause an accident. Remember that the drill will be hot. Use caution until it cools.)

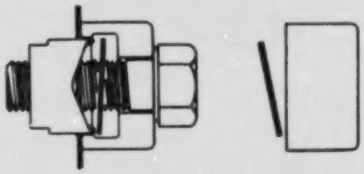
- I. Separate knockout punch cutter from die and threaded ram
- J. Insert threaded ram through drilled hole; replace cutter on threaded ram
- K. Close hydraulic valve; pump handle until cutter pulls through metal

  (NOTE: After cutter is pulled through, knockout punch is easily removed.)

JOB SHEET #1

L. Open valve and remove cutter from threaded ram; shake out punched metal (Figure 14)

FIGURE 14



Slug falls free in die.

Tip die to remove slug.

M. Replace cutter on ram, making sure that it is properly lubricated

(NOTE: Have the instructor evaluate your work.)

N. Clean work area, and put away equipment and materials

POWER EQUIPMENT
UNIT II

JOB SHEET #2 — BEND A 90-DEGREE STUB, USING A HYDRAULIC PIPE BENDER

I. Equipment and materials

- A. Hydraulic pipe bender
- B. 5 feet of 1-inch rigid galvanized conduit
- C. Ruler
- D. Marking pencil

II. Procedure

(NOTE: The procedure that follows is specifically for a Greenlee #880 bender. Other benders may vary slightly in measurements, but the procedure will be basically the same.)

- A. Assemble hydraulic bender using a 1-inch shoe and pipe supports
- B. Check chart on bender for minimum stub length, required deduction for stub, and ram travel measurement; record

  Minimum stub length = ______________________

  Stub Deduction = ______________________

  Ram travel = ______________________

- C. Mark stub length (24 inches) on pipe
- D. Subtract stub deduction measurement from 24-inch mark, and make a second mark at that point
- E. Place pipe in bender shoe, matching center mark of shoe with second mark on pipe
- F. Close hydraulic pump valve, and pump handle until ram travel gauge indicates amount of travel for a 1-inch pipe with a 90-degree bend
- G. Release hyraulic pump valve, and allow ram to return fully before removing pipe

JOB SHEET #2

H. Check height of stub and accuracy of 90-degree bend

(NOTE: Show work to instructor for evaluation.)

I. Disassemble bender, clean work area, and return equipment and materials to their proper places

POWER EQUIPMENT
UNIT II

JOB SHEET #3 — MAKE OFFSET AND 90-DEGREE BENDS, USING AN ELECTRIC PVC HEATER

I. Equipment and materials

- A. 10 feet of 1/2-inch PVC conduit
- B. Electric PVC heater
- C. Instructions for PVC heater
- D. Small pail of water
- E. Shop rag or sponge
- F. Piece of board at least 1 inch thick and as wide as desired offset
- G. Nails to tack up piece of board
- H. Eye protection
- I. Gloves

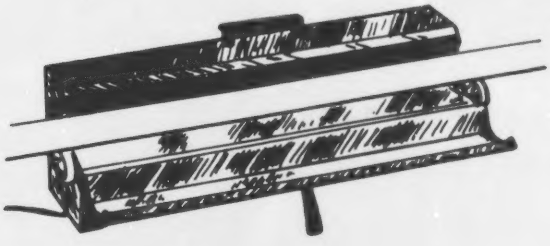
II. Procedure

- A. Heat conduit and make a 90-degree bend
  1. Read instructions for PVC heater
  2. Put on eye protection and gloves
  3. Plug PVC heater into 115-volt AC outlet and turn on; allow unit to preheat for fifteen minutes in closed position

JOB SHEET #3

4. Open unit and insert PVC as shown in Figure 15

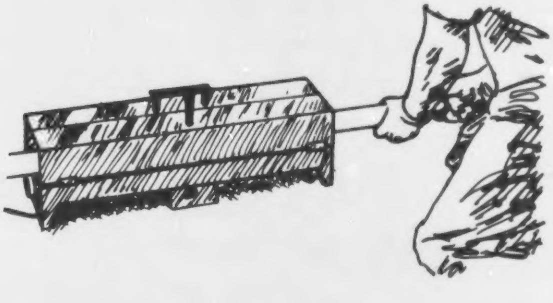
FIGURE 15



5. Close unit, and rotate PVC for one to two minutes or until it becomes pliable enough for bending (Figure 16)

(NOTE: Constantly turn conduit as it heats.)

FIGURE 16



6. Remove PVC from heating chamber when it becomes soft and is easily bent

(NOTE: Experience will help in determining when PVC is pliable for bending. Make sure that conduit is adequately heated. Larger pieces of conduit tend to kink unless adequately heated.)

(CAUTION: Conduit will be very hot. Handle it carefully to avoid burns.)

JOB SHEET #3

7. Turn off PVC heater

8. Form the 90-degree bend by hand on a flat surface

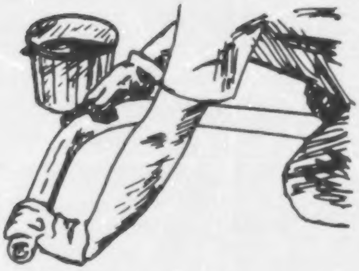
   (NOTE: Another method of forming the 90-degree bend is to push the conduit into a corner of the room, leaving the desired amount of straight conduit on each side of the bend.)

9. Apply water-soaked rag or sponge to PVC to set the bend (Figure 17)

   (CAUTION: Do not use water next to the electric heater because of shock hazard.)

   (NOTE: If bend is made in the corner of the room, an alternate method of setting the bend is to use straight boards to hold the conduit against the wall until it cools and hardens.)

   FIGURE 17



B. Heat conduit and make an offset bend

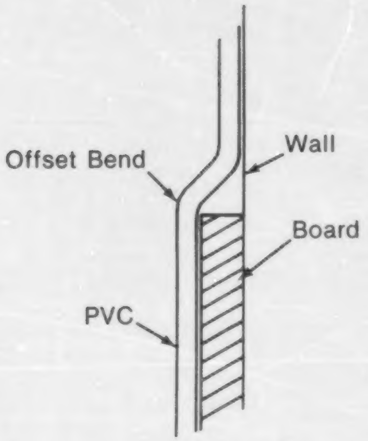
   1. Determine amount of offset desired

   2. Turn on PVC heater and allow it to preheat for fifteen minutes in closed position

JOB SHEET #3

3. Nail prepared piece of board to wall so that PVC may be shaped by placing it against the wall and then bending it away from the wall to lie parallel to outer edge of board as shown in Figure 18

FIGURE 18



4. Open PVC heater, and insert PVC

5. Close unit, and rotate PVC for one to two minutes or until it becomes pliable enough for bending

6. Remove PVC from heating chamber when it becomes soft and is easily bent

CAUTION: Conduit will be very hot. Handle it carefully to avoid burns.)

7. Turn off PVC heater

8. Lay conduit against wall and against board as shown in Figure 18, holding the ends against the board and the wall until PVC cools and hardens

(NOTE: Show work to instructor for evaluation and comment.)

9. Deenergize PVC heater

10. Clean work area and put away all equipment and materials

POWER EQUIPMENT
UNIT II

JOB SHEET #4 — CUT, REAM, AND THREAD STEEL PIPE WITH A POWER THREADER

I. Equipment and materials

  A. Power threader

  B. Stand for power threader

  C. Pipe cutter accessory

  D. Pipe reamer accessory

  E. Adjustable die head accessory

  F. Tool carriage accessory

  G. Carriage lever accessory

  H. Instructions for power threader and accessories

  I. Oiler and thread-cutting oil

  J. Clean cloth

  K. Eye protection

  L. Gloves

  M. Length of steel pipe

II. Procedure

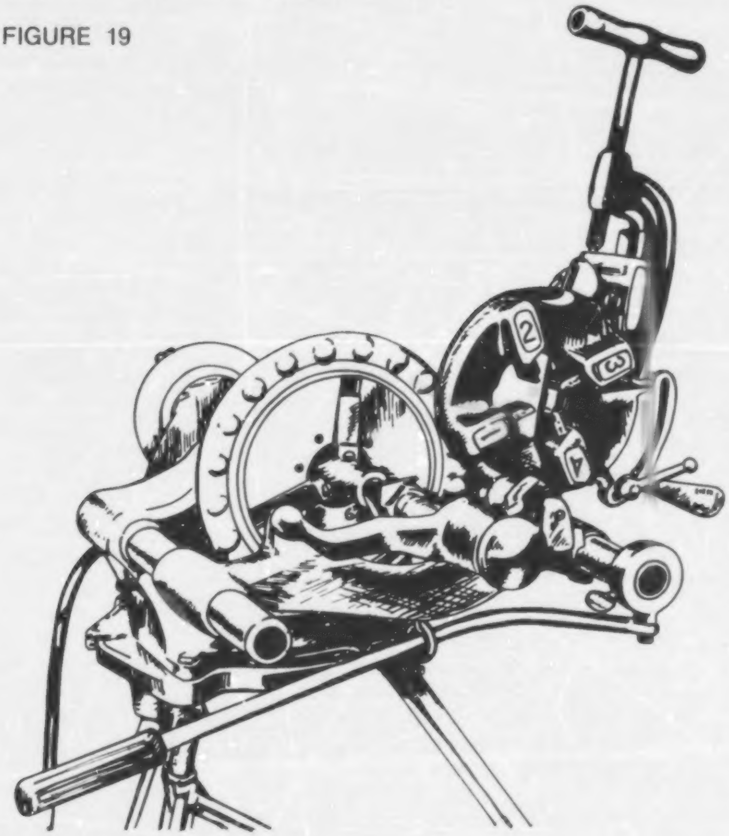
  A. Read instructions for power threader and accessories

  B. Install power threader on stand

JOB SHEET #4

C. Install pipe cutter, pipe reamer, adjustable die head, tool carriage, and carriage lever on power threader (Figure 19)

FIGURE 19



D. Put on eye protection and gloves

E. Insert pipe into power threader, allowing pipe to extend far enough to clear chuck; tighten chuck jaws and rear centering device

F. Mark pipe at point where cut is to be made

G. Put tool support bar in position to support cutter handle

H. Apply cutter to pipe, allowing cutter handle to rest on tool support bar

I. Tighten cutter blade to contact pipe at marked point

J. Energize power threader

K. Turn power drive switch to FORWARD; turn cutter blade into pipe until pipe cut is completed

JOB SHEET #4

L. Turn off motor, and lay cutter against tool rest

M. Place reamer in pipe end, allowing reamer handle to rest against tool support bar

N. Turn on motor

O. Press reamer into pipe to remove burrs

P. Turn off motor, and lay reamer against tool rest

Q. Place threader die head on pipe

R. Cut required number of threads, keeping oil on die stock until threads are cut

S. Turn off motor

(CAUTION: Always allow machine to come to a complete stop before reversing direction.)

T. Turn on motor, turn power drive switch to REVERSE, and remove threader from pipe

U. Deenergize power threader

(NOTE: Show threaded pipe to instructor for evaluation and comments.)

V. Dismantle equipment, clean work area, and put away all materials and equipment

POWER EQUIPMENT
UNIT II

TEST

NAME ______________________________ SCORE ______________

1. Match to their correct definitions terms associated with power equipment. Write the correct numbers in the blanks.

_____a. Specially formulated oil for hydraulic pumps

_____b. Any opening that may close and bind a finger or hand

_____c. Portion of drill that holds the bit

_____d. Plastic pipe

_____e. Handle set across a power tool to prevent the tool from turning

_____f. Tool used to make various angles or bends in conduit

_____g. Device used to transfer hydraulic pressure to a mechanical device

_____h. Device used to make openings for conduit in metal enclosures

_____i. Using pressurized fluid to accomplish work

_____j. Hardened steel device used to cut holes in metal boxes

_____k. Component that backs up cutter on opposite side of metal box

1. Bender
2. Chuck
3. Cross handle
4. Cutter
5. Die
6. Hydraulic
7. Hydraulic oil
8. Knockout punch
9. Pinch point
10. Polyvinyl chloride (PVC)
11. Ram

2. List typical electrical power equipment.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

TEST

3. State general safety rules for using power equipment.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

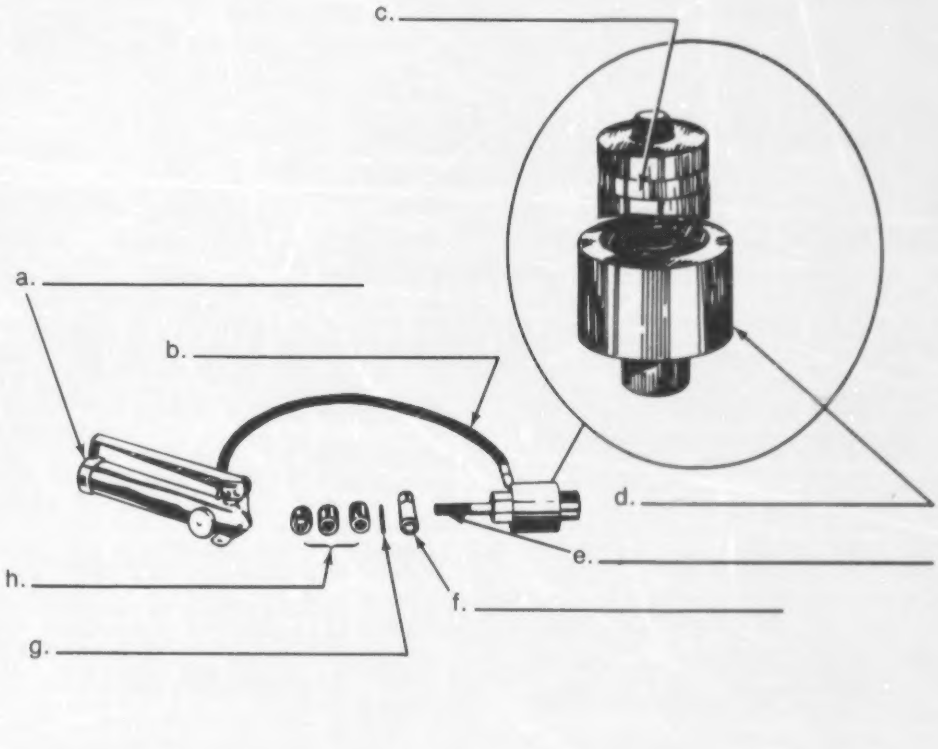
e. ______________________________

f. ______________________________

g. ______________________________

h. ______________________________

4. Label the parts of the hydraulic knockout set illustrated below.



TEST

5. State specific safety rules for using hydraulic knockout sets.

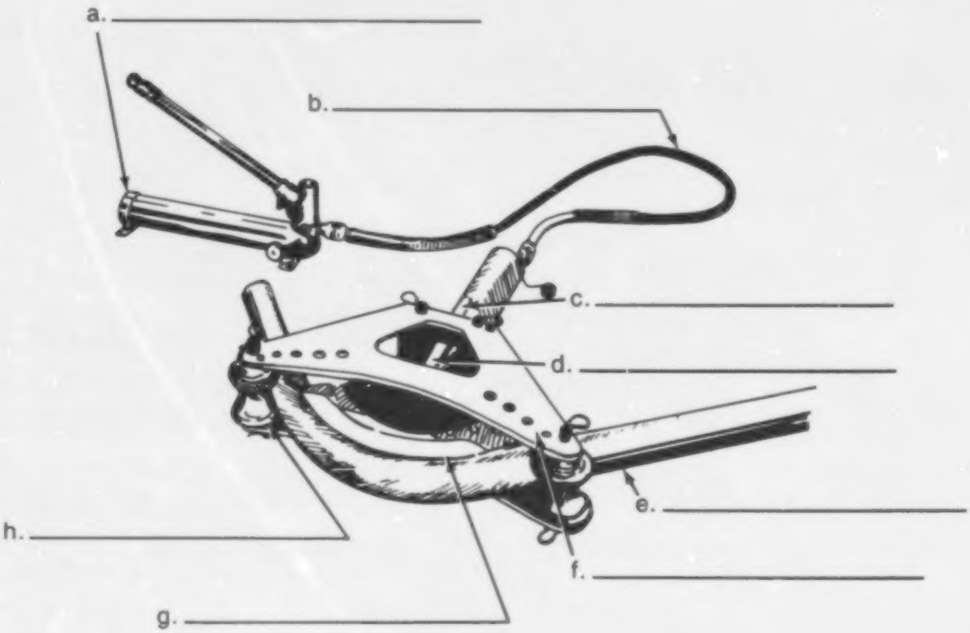
   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

6. Label the parts of the hydraulic pipe bender illustrated below.



TEST

7. State specific safety rules for using hydraulic pipe benders.

   a. ____

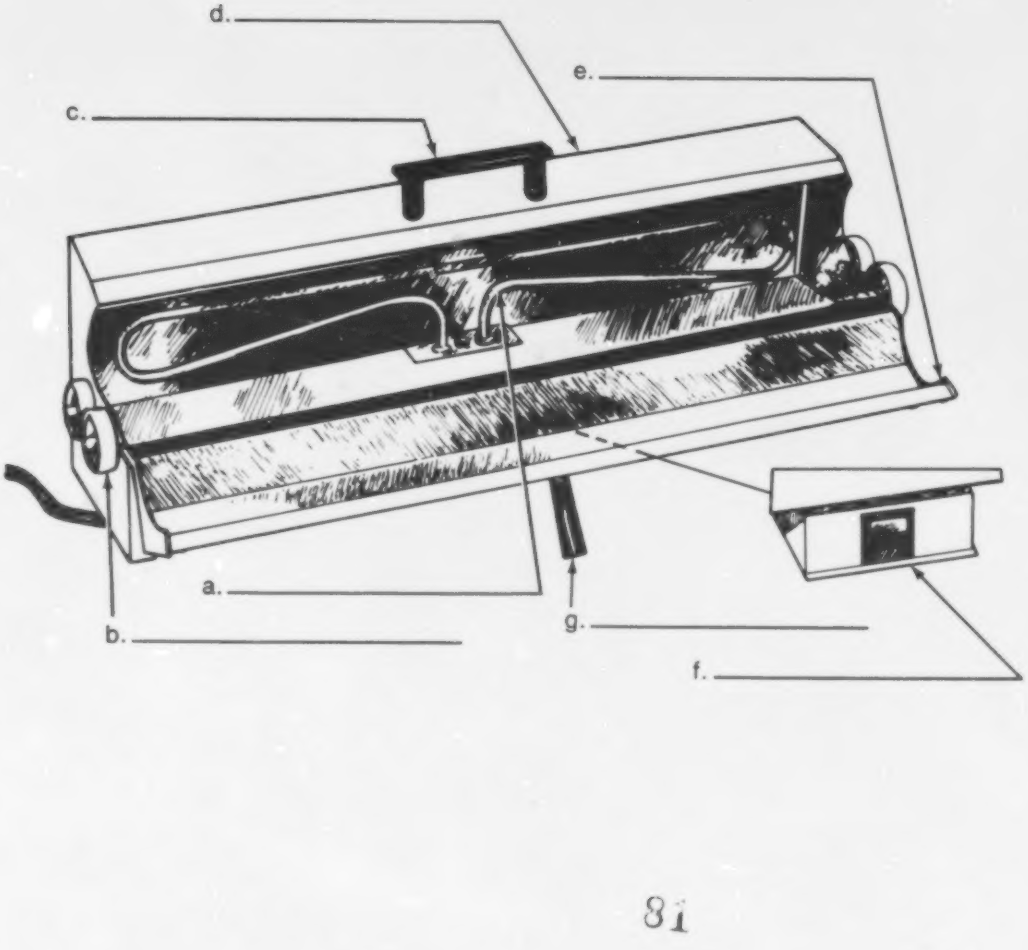
   b. ____

   c. ____

   d. ____

   e. ____

8. Label the parts the electric polyvinyl chloride (PVC) heater illustrated below.



TEST

9. State specific safety rules for using electric polyvinyl chloride (PVC) heaters.

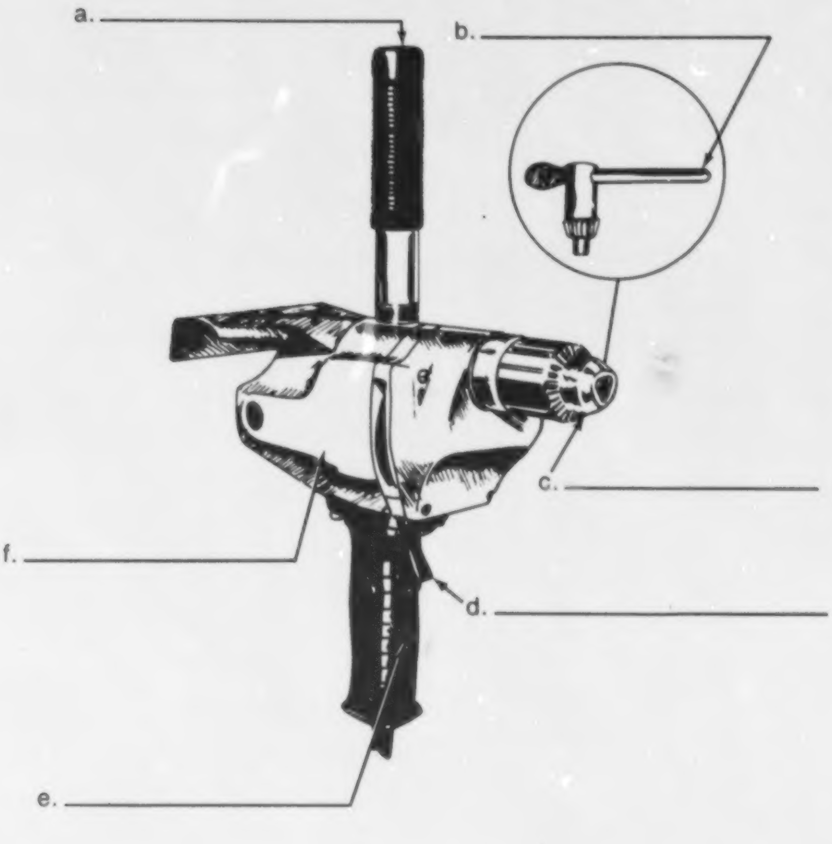
   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

10. Label the parts of the power drill illustrated below.



TEST

11. State specific safety rules for using power drills.

a. ______________________________

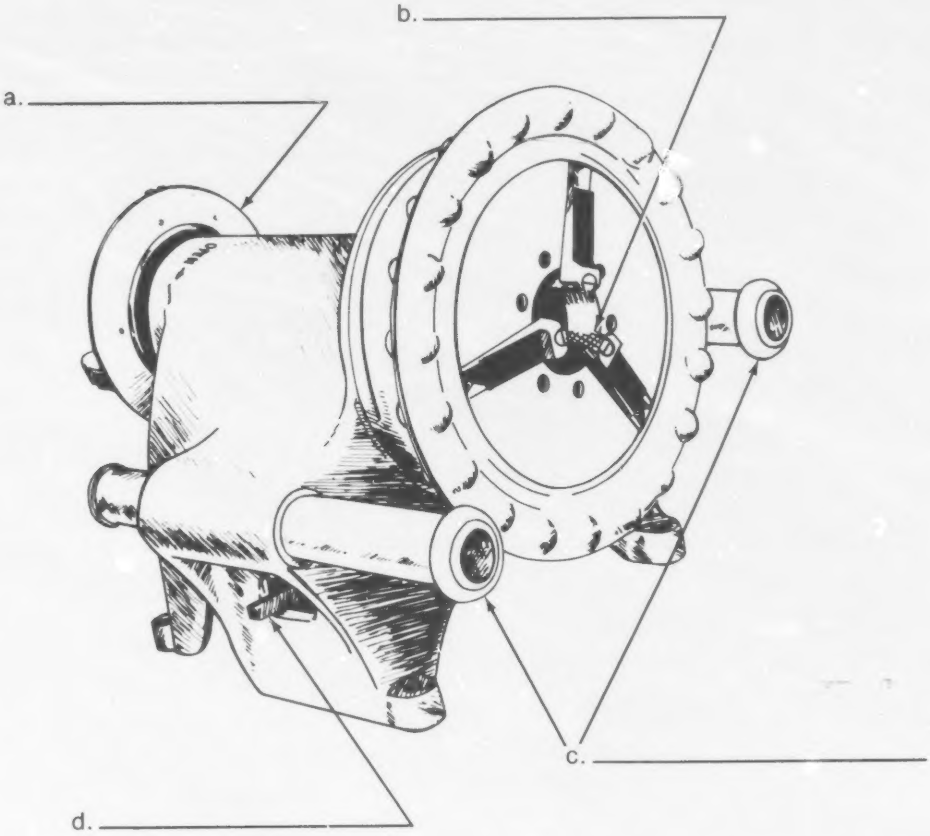
b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

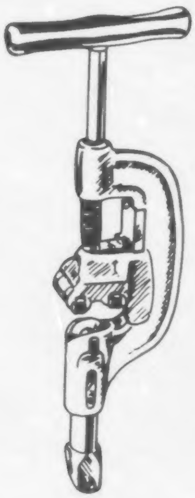
12. Label the parts of the power threader illustrated below.

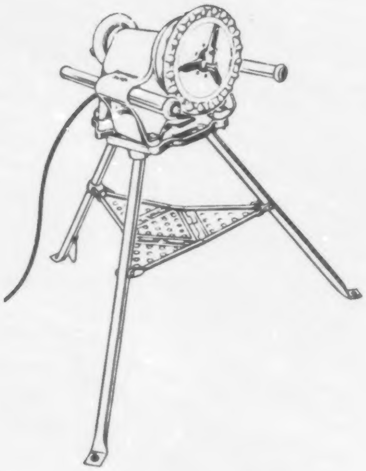


TEST

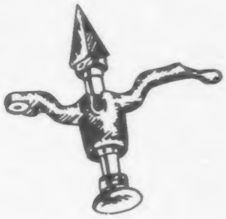
13. Identify the following power threader accessories. Write the correct names in the blanks.

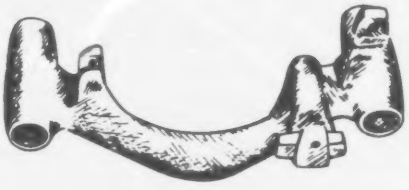
Oiler
Carriage lever
Cutter
Power threader stand
Reamer
Tool carriage
Adjustable die head





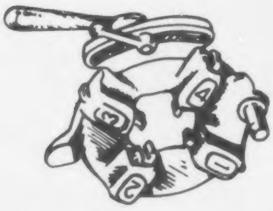
a. ______________________________ b. ______________________________

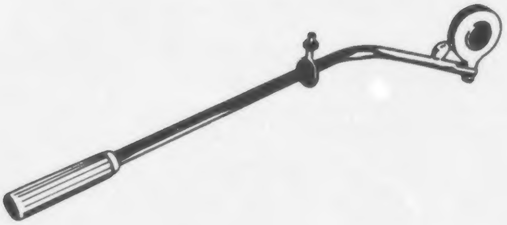




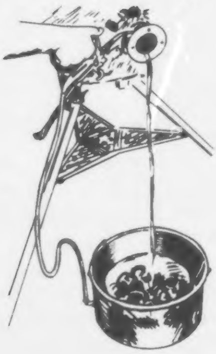
c. ______________________________ d. ______________________________

TEST





e. ______________________ f. ______________________



g. ______________________

14. State specific safety rules for using power threaders.

    a. ______________________

    b. ______________________

    c. ______________________

    d. ______________________

    e. ______________________

    f. ______________________

(NOTE: Test question 15 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

15. Demonstrate the ability to

    a. Use a hydraulic knockout punch.

    b. Bend a 90-degree stub, using a hydraulic pipe bender.

TEST

c. Make offset and 90-degree bends, using an electric PVC heater.

d. Cut, ream, and thread steel pipe with a power threader.

POWER EQUIPMENT
UNIT II

ANSWERS TO TEST

1. a. 7
   b. 9
   c. 2
   d. 10
   e. 3
   f. 1
   g. 11
   h. 8
   i. 6
   j. 4
   k. 5

2. a. Hydraulic knockout
   b. Hydraulic bender
   c. Electric PVC heater
   d. Power drill
   e. Power threader

3. a. Always follow manufacturer's operating instructions
   b. Never place hands in a pinch point
   c. Use eye protection when cutting or drilling
   d. Wear gloves when working with hot equipment or materials
   e. Always secure loose clothing such as shirt sleeves and shirttails
   f. Never exceed rated capacity of equipment
   g. Never leave running equipment unattended
   h. Never remove protective guards from equipment

4. a. Hydraulic pump
   b. Hydraulic hose

ANSWERS TO TEST

c. Knockout cutter

d. Die

e. Hydraulic threaded ram

f. Screw sleeve

g. ½-inch knockout adapter

h. Spacers

5. a. Never substitute brake fluid for hydraulic oil

   b. Never disconnect hose when it is under pressure

   c. Do not use near live electrical parts

   d. Never force pump handle

6. a. Hydraulic pump

   b. Hydraulic hose

   c. Ram travel gauge

   d. Hydraulic ram

   e. Pipe

   f. Bender frame

   g. Bender shoe

   h. Pipe support

7. a. Never substitute brake fluid for hydraulic oil

   b. Never disconnect hose when it is under pressure

   c. Never place hands near ram or shoe while bending

   d. Always use proper side of conduit shoe and support

   e. Be sure that floor area is clear for pipe movement

ANSWERS TO TEST

8. a. Heating element
   b. Pipe rollers
   c. Carrying handle
   d. Heater outer case
   e. Door
   f. On/off switch
   g. Insulated door handle

9. a. Never use in wet locations
   b. Always wear gloves when handling hot heater or pipe
   c. Use only with PVC conduit
   d. Always turn bender off when not in use

10. a. Cross handle
    b. Chuck key
    c. Chuck
    d. Power trigger
    e. Forward/reverse switch
    f. Drill motor

11. a. Always wear eye protection
    b. Check area to be drilled for hidden wires or pipes
    c. Hold drill securely with both hands
    d. Never drill while off balance
    e. Place small objects to be drilled in a vise

ANSWERS TO TEST

12. a. Rear pipe chuck
    b. Front pipe chuck
    c. Tool support bars
    d. Forward/reverse/off switch

13. a. Cutter
    b. Power threader stand
    c. Reamer
    d. Tool carriage
    e. Adjustable die head
    f. Carriage lever
    g. Oiler

14. a. Always wear eye protection
    b. Always wear tight-fitting clothing
    c. Use gloves when handling pipe
    d. Never place hands near turning pipe
    e. Let threader come to a complete stop before removing pipe or reversing direction
    f. Always use a brush to clear thread cuttings

15. Performance skills evaluated to the satisfaction of the instructor

BLUEPRINT READING
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to determine the number and size of wires required for each conduit run, calculate conduit size, and calculate wire sizes for motor circuits on industrial electrical wiring jobs. The student should also be able to read a rule and use a rule to measure objects accurately. The student will show this knowledge by completing assignment sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with blueprint reading.
2. List information commonly found on electrical blueprints.
3. Name electrical blueprint symbols.
4. Label types of blueprints.
5. List typical electrical specifications for bidding.
6. Circuit a print.
7. Arrange in order steps for determining motor-circuit wire sizes.
8. State steps for determining conduit size.
9. Read measurements on a standard rule.
10. Use a rule to measure objects.
11. Circuit a print.
12. Determine wire sizes for blueprint conduit runs.

BLUEPRINT READING
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order materials planned to supplement the unit.

1. One small commercial building blueprint for each student. Blueprint should illustrate electrical circuitry; outlets; switches; and normal information about fixtures, motors, and panels.

2. Sample specification sheets for commercial electrical wiring jobs. Obtain one for each student.

3. Copies of requisition forms for ordering supplies for an electrical wiring job.

4. Several copies of electrical supply catalogs for student practice in filling out requisition forms.

5. Several copies of residential blueprints (generally available from builders) so that students may practice circuiting electrical jobs.

   (NOTE: Show the students how these prints differ from industrial electrical prints.)

6. Current edition of *National Electrical Code,* available from the National Fire Protection Association, Batterymarch Park, Quincy, Massachusetts 02269. Obtain one for each student.

7. Current edition of *National Electrical Code Blueprint Reading,* available from American Technical Publishers, Incorporated, 12235 S. Laramie Avenue, Alsip, Illinois 60658.

8. Copies of your school's building construction blueprints to familiarize students with this type of construction and with industrial prints.

B. Plan a field trip to a commercial or industrial construction site where electrical work is being done.

C. Prepare a presentation on the application of the *National Electrical Code (NEC)* as it pertains to blueprints and layouts.

D. Invite a guest speaker to speak to the class.

EXAMPLES: A factory representative to speak on electric motors, electrical panels, and types of wiring and conductors

An electrical engineer to speak about specifications and drafts of electrical blueprints

SUGGESTED ACTIVITIES

E. Plan a field trip to the drafting department of an industrial plant.

F. Arrange for an electrical contractor to speak to the class about takeoffs, estimates and bids, and the enforcement of the *NEC*.

G. Make transparencies.

H. Provide students with objective sheet.

I. Discuss unit and specific objectives.

J. Provide students with information and assignment sheets.

K. Discuss information and assignment sheets.

   1. Discuss terms and definitions, using Information Sheet, Section I. Have a blueprint of an actual construction project available to assist students in understanding such terms as *circuiting of print, rough-in,* and *trim-out.*

   2. Discuss the kinds of information commonly found on blueprints, using Information Sheet, Section II. Secure a blueprint for a large building from a local contractor. (Normally, a contractor will loan such a blueprint to you for a short time.) Familiarize the students with blueprint cross-referencing and with the process used to determine the best structural place for running conduit or placing equipment.

   3. Discuss electrical symbols for blueprints, using Information Sheet, Section III. Have available actual equipment such as receptacles, switches, and panels to show students how blueprint symbols correlate to actual equipment. Show students a blueprint, and point out its Key to Symbols section. Explain that normally a list of electrical symbols is submitted with each set of electrical blueprints, and that a Key to Abbreviations may also be submitted so that persons using the blueprint can readily identify abbreviations and symbols used in the print.

   4. Discuss types of blueprints, using Information Sheet, Section IV and Transparencies #1 through #6. Explain why it is necessary for electricians to have access to plot plans and other drawings, in addition to electrical drawings. Explain that electricians must understand how a building is going to be constructed so that conduit can be routed in a way that will not interfere with the work of other tradespeople.

   5. Discuss typical electrical specifications for bidding, using Information Sheet, Section V. Secure from one of the local electrical contractors a typical specifications sheet used in recent bidding.

      (NOTE: Usually these specifications sheets can be acquired easily from a contractor who is used to bidding large jobs.)

SUGGESTED ACTIVITIES

6. Explain how to determine the needed number of wires and conduit runs, using Information Sheet, Section VI and Assignment Sheet #3. A tour of your own shop or campus may show the students how one conduit can house several circuits for different types of equipment. The student will also be able to see how the number of wires needed affects the requirement for conduit size.

   Explain to students that the drawing used in both parts of Assignment Sheet #3 will also be used to complete Assignment Sheet #4. Stress to students that each revision to the drawing must be checked by the instructor before the student proceeds to the next assignment.

7. Discuss the steps for determining wire size for motor circuits, using Information Sheet, Section VII and Assignment Sheet #4. To follow this discussion, it will be necessary for each student to have available a current copy of the *NEC*. Remind students that Article 430 deals with most of the subjects concerning motors and includes the sizing of circuit conductors for individual and multimotor circuits.

8. Discuss steps for calculating conduit size, using Information Sheet, Section VIII. Again, provide each student with a current edition of the *NEC*. Make sure that the students understand that Tables 3A and 3B in Chapter 9 are the tables they will use to figure conduit size. Point out that the *NEC* provides conduit sizing tables to make the job easier for the electrician and to help the electrician determine the maximum number of conductors that may be pulled in. Attempting to pull in more conductors than the *Code* allows, causes more work and violates the *Code*. Work that violates the *Code* will be turned down by the inspector.

9. Discuss the steps for properly reading a rule, using Information Sheet, Section IX, Transparencies #7 through #9, and Assignment Sheets #1 and #2. Make sure that each student has a rule. Discuss the importance of being able to interpret division and graduation marks on various rules. In order to read a blueprint, the electrical technician must be able to check measurements and interpret different scales used on blueprints.

L. Give test.

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Electrical Floor Plan

2. TM #2 — Plot Plan

SUGGESTED ACTIVITIES

3. TM #3 — Foundation Plan

4. TM #4 — Floor Plan

5. TM #5 — Elevations

6. TM #6 — Details

7. TM #7 — Graduations on a Rule

8. TM #8 — Reading the Eighths Rule

9. TM #9 — Reading the Sixteenths Rule

E. Assignment sheets

1. Assignment Sheet #1 — Read Measurements on a Rule

2. Assignment Sheet #2 — Use a Rule to Measure Objects

3. Assignment Sheet #3 — Circuit a Print

4. Assignment Sheet #4 — Determine Wire Sizes for Blueprint Conduit Runs

F. Answers to assignment sheets

G. Test

H. Answers to test

III. Unit references

A. Gebert, Kenneth L. *National Electrical Code Blueprint Reading,* 8th ed. Chicago, Illinois: American Technical Publishers, Inc., 1980.

B. Hendrix, Laborn J. "Bud." *Bricklaying: Basic Core.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center and The Associated General Contractors of America, 1983.

C. Hendrix, Laborn J. "Bud." *Millwright.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center and The Associated General Contractors of America, 1980.

D. National Fire Protection Association. *National Electrical Code 1981.* Boston, Massachussets: National Fire Protection Association, 1980.

E. Siebert, Leo N. *Introduction to Industrial Electricity-Electronics.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1981.

F. Taylor, Mark. *Residential Wiring.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1978.

BLUEPRINT READING
UNIT III

INFORMATION SHEET

I. Terms and definitions

   A. Circuit a print — To mark a blueprint with lines and symbols to help determine number of circuits, amount and sizes of wires, amount and sizes of conduit, and number and sizes of boxes needed

   B. Takeoff — Taking information from a circuited blueprint and converting it to a supply list

   C. Make requisition — To convert takeoff list into an order form that includes catalog numbers for purchasing materials and supplies

   D. Home run — Conduit and wire that runs between breaker panel and first outlet or junction box on that circuit or circuits

   E. Make-up — Process of making all splices and connections, leaving the job ready for other tradespeople such as insulators, sheetrockers, and painters

   F. Rough-in — Process of installing outlet boxes, breaker panel, conduit, pulling wire, and grounding connections

   (NOTE: Rough-in inspection is made when rough-in is completed. The *National Electrical Code* [*NEC*] enforcement authority inspects the work to determine if it conforms to *Code* requirements.)

   G. Trim-out — Process of installing, energizing, and testing all circuits, switches, receptacles, and fixtures; and connecting and testing motors and equipment, leaving them ready for use

II. Information commonly found on electrical blueprints (Transparency #1)

   A. Sizes

   EXAMPLES: Panels, feeders, branch circuits

   B. Types and quality of building materials

   EXAMPLES: Copper or aluminum, electrical metallic tubing (EMT)

   C. Methods of construction

   EXAMPLES: Conduit, raceways, cabletrays

INFORMATION SHEET

D. Material symbols

EXAMPLES: Light fixtures, exhaust fans, and other special items

(NOTE: Material symbols identify special items that are listed on a separate materials sheet. These sheets are usually attached to the specifications.)

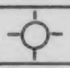
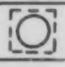
E. Miscellaneous information

EXAMPLES: Owner's name and address, contractor's name and address, location of new structure, completion date, guarantees, blueprint number

F. Legend of specific symbols and abbreviations used to identify electrical equipment

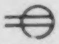
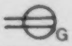
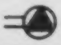
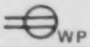
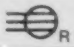
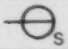
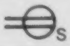
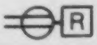
III. Electrical blueprint symbols

A. General outlets

Type	Symbol	
	Ceiling	Wall
Standard outlet	○	-○
Exit light	ⓧ	-ⓧ
Ceiling light		
Ceiling lighting outlet for recessed fixture		
Lamp holder	Ⓛ	-Ⓛ
Lamp holder with pull switch	Ⓛ$_{PS}$	-Ⓛ$_{PS}$
Junction box	Ⓙ	-Ⓙ
Drop cord	Ⓓ	
Fan outlet	Ⓕ	-Ⓕ

INFORMATION SHEET

B. Convenience outlets

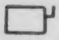
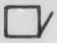
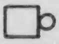
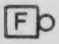
Type	Symbol
Duplex receptacle	
Duplex grounding outlet	
Special purpose (description in specifications)	
Duplex special purpose	
Weatherproof	
Range	
Switch with single receptacle	
Switch with double receptacle	
Floor	
Radio and double receptacle	

C. Switch outlets

Type	Symbol
Single-pole switch	S
Double-pole switch	S_2
Three-way switch	S_3
Four-way switch	S_4
Switch and pilot lamp	S_P
Weatherproof switch	S_{WP}
Fused switch	S_F

INFORMATION SHEET

D. Panels, circuits, auxiliary, and miscellaneous

Type	Symbol
Thermostat	Ⓣ or Th
Lighting panel	■
Power panel	▨
Controller	⊠
Isolating switch	
Exposed branch circuit	-----
Branch circuit concealed in floor	— - —
Branch circuit concealed in ceiling or wall	——
Auxiliary system circuit	—·—·—
Push button	⊡
Buzzer	
Bell	
Fire alarm bell	
Automatic fire alarm device	FS
Interconnection box	□

IV. Types of blueprints (Transparencies #2-#6)

(NOTE: Blueprints are sometimes referred to as *architectural drawings.*)

A. Plot plan

B. Foundation plan

C. Floor plan

D. Elevations

E. Details

INFORMATION SHEET

V. Typical electrical specifications for bidding

A. Minimum standards

EXAMPLE: The contractor shall install the complete electrical system according to national and local electrical codes, as per plans and specifications.

B. Type of equipment

EXAMPLES: All switches, duplex receptacles, and other outlets shall be in conduit (EMT will be acceptable). Electrical contractor shall furnish all lighting fixtures as per specifications or approved substitutes.

C. Type of installation

EXAMPLES: Electrical service equipment shall be of units specified on plans or shall be approved substitutes or like quality. All work shall be done in coordination with other crafts.

D. Special instructions

EXAMPLE: Receptacle circuits shall include an equipment grounding conductor of proper size.

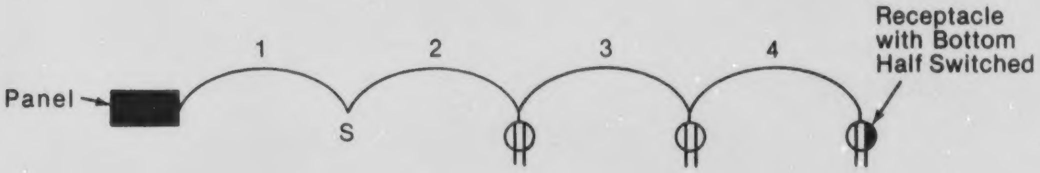
VI. Circuiting a print (Assignment Sheet #3)

A. Determine circuit load

B. Determine wires needed to serve each outlet

1. Single-phase 120/240-volt system (Figures 1-4)

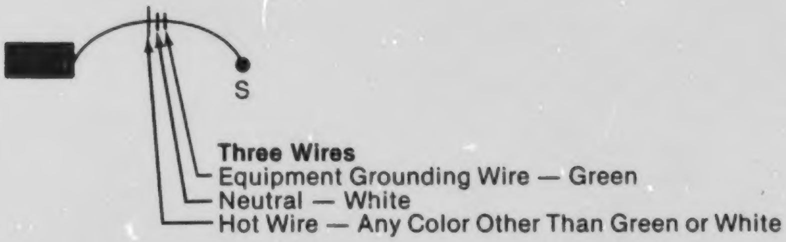
FIGURE 1



INFORMATION SHEET

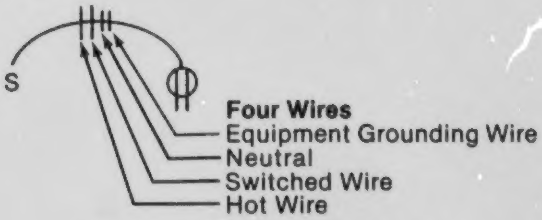
a. Run #1 requires — One hot wire
One grounded conductor (neutral)
One equipment grounding wire (single long mark)

FIGURE 2


S
Three Wires
Equipment Grounding Wire — Green
Neutral — White
Hot Wire — Any Color Other Than Green or White

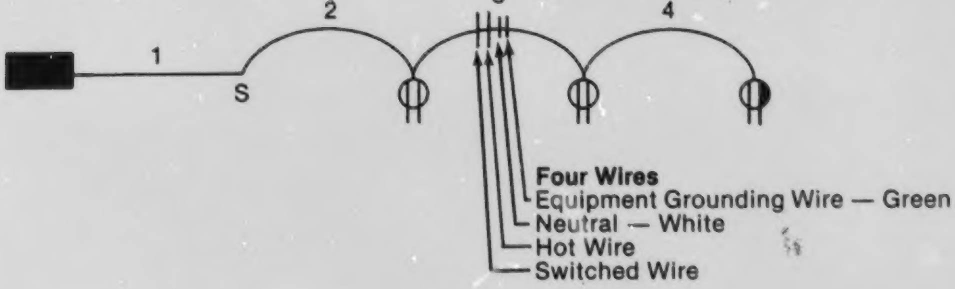
b. Run #2 requires — One hot wire for downstream receptacle
One switch wire for switched receptacle
One neutral conductor
One equipment grounding wire

FIGURE 3


S
Four Wires
Equipment Grounding Wire
Neutral
Switched Wire
Hot Wire

c. Runs #3 and #4 require — One hot wire
One switched wire
One neutral wire
One equipment grounding wire

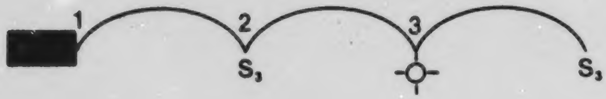
FIGURE 4


1
2
3
4
S
Four Wires
Equipment Grounding Wire — Green
Neutral — White
Hot Wire
Switched Wire

INFORMATION SHEET

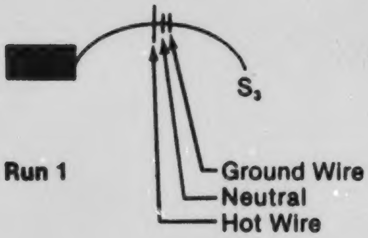
2. Single-phase 120/240-volt system with three-way switch (Figures 5-8)

FIGURE 5



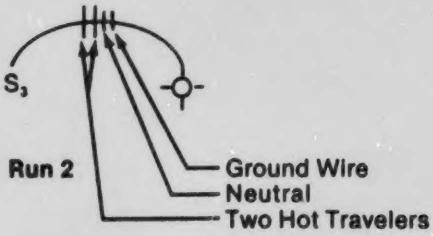
a. Run #1 requires — One hot wire
One neutral wire
One ground wire

FIGURE 6


S_3
Run 1
Ground Wire
Neutral
Hot Wire

b. Run #2 requires — Two hot travelers
One neutral wire
One ground wire

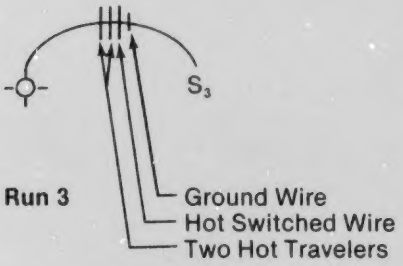
FIGURE 7


S_3
Run 2
Ground Wire
Neutral
Two Hot Travelers

INFORMATION SHEET

c. Run #3 requires — Two hot travelers
One hot switched wire
One ground wire

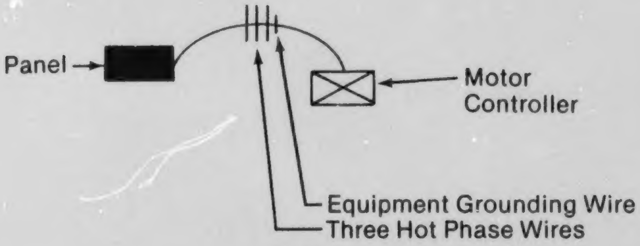
FIGURE 8



S_3
Run 3
Ground Wire
Hot Switched Wire
Two Hot Travelers

3. Three-phase four-wire wye system (Figure 9)

FIGURE 9



Panel
Motor Controller
Equipment Grounding Wire
Three Hot Phase Wires

VII. Steps for determining motor-circuit wire sizes (Table 1; Assignment Sheet #4)

(NOTE: *NEC* Article 430-148 gives normal amperages for single-phase motors, and Article 430-150 gives similar information for three-phase motors.)

A. Determine motor size, voltage, and phase from print

INFORMATION SHEET

B. Determine full-load amperes from *NEC* Articles 430-148 and 430-150

(NOTE: Full-load amperes may also be determined from nameplate data.)

C. Determine circuit ampacity from *NEC* Article 430-22 (continuous-duty motors)

D. Determine wire insulation type, using *NEC* Table 310-13

EXAMPLE: THW would be the type of heat-resistant insulation needed for a dry location in a machine shop where the temperature does not exceed 75°C at any time.

E. Determine wire size from *NEC* Table 310-16

(NOTE: According to *NEC* 210-19, conductors shall be rated to prevent a voltage drop exceeding 3 percent. Number 12 wire is normally required on motor circuits rated 1 to 16 amperes.)

EXAMPLE:

TABLE 1

Motors	**Full-Load Amps Per *NEC* 430-148 *NEC* 430-150**	**Calculated Circuit Ampacity Per *NEC* 430-22**	**THW Wire size *NEC* 310-16**
1 hp 240 Volts 1 ϕ	8.0	10.0	#12
2 hp 240 Volts 3 ϕ	6.8	8.5	#12
3 hp 240 Volts 3 ϕ	9.6	12.0	#12
7.5 hp 240 Volts 3 ϕ	22.0	27.5	#10
15 hp 240 Volts 3 ϕ	42.0	52.5	# 6

VIII. Steps for determining conduit size (Table 2)

A. Determine wire size

B. Determine number of wires in conduit run

INFORMATION SHEET

C. Determine conduit size from Tables 3A and 3B in *NEC* Chapter 9

(NOTE: On a long run of conduit with heavy fill, you may need to go to the next size larger conduit for ease of installation.)

EXAMPLE:

TABLE 2

Circuit Number	**Wire Size**	**Insulation**	**Number of Wires**	**Conduit Size per Tables 3A and 3B**
1	#12	TW	6	1/2"
2	#8	THHN	8	1"
3	#6	THW	5	1 1/4"
4	#12	THHN	8	1/2"
5	#10	THWN	6	1/2"

IX. Reading measurements on a standard rule (Transparencies #7-#9; Assignment Sheets #1 and #2)

(NOTE: All rules read similarly. Some rules are graduated with more divisions per inch than others. Layout tapes are marked 16 inches on center.)

A. Determine the number of graduations per inch

1. Locate at the zero end of rule the small figure that designates divisions per inch
2. Count divisions in 1 inch

(NOTE: Practice to gain skill in determining the divisions.)

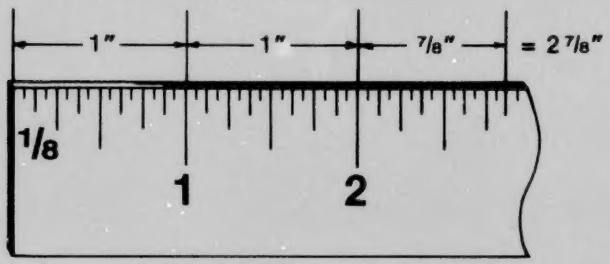
INFORMATION SHEET

B. Determine inches and fractions of an inch

1. Count graduations in that fraction of an inch beyond last full inch (Figure 10)

   EXAMPLE:

FIGURE 10



2. Add fraction to last full inch

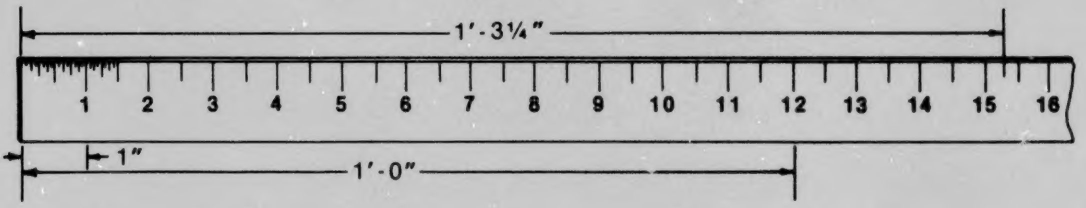
   (NOTE: In the example above, the total amount equals 2 7/8 inches.)

C. Reduce fraction if possible

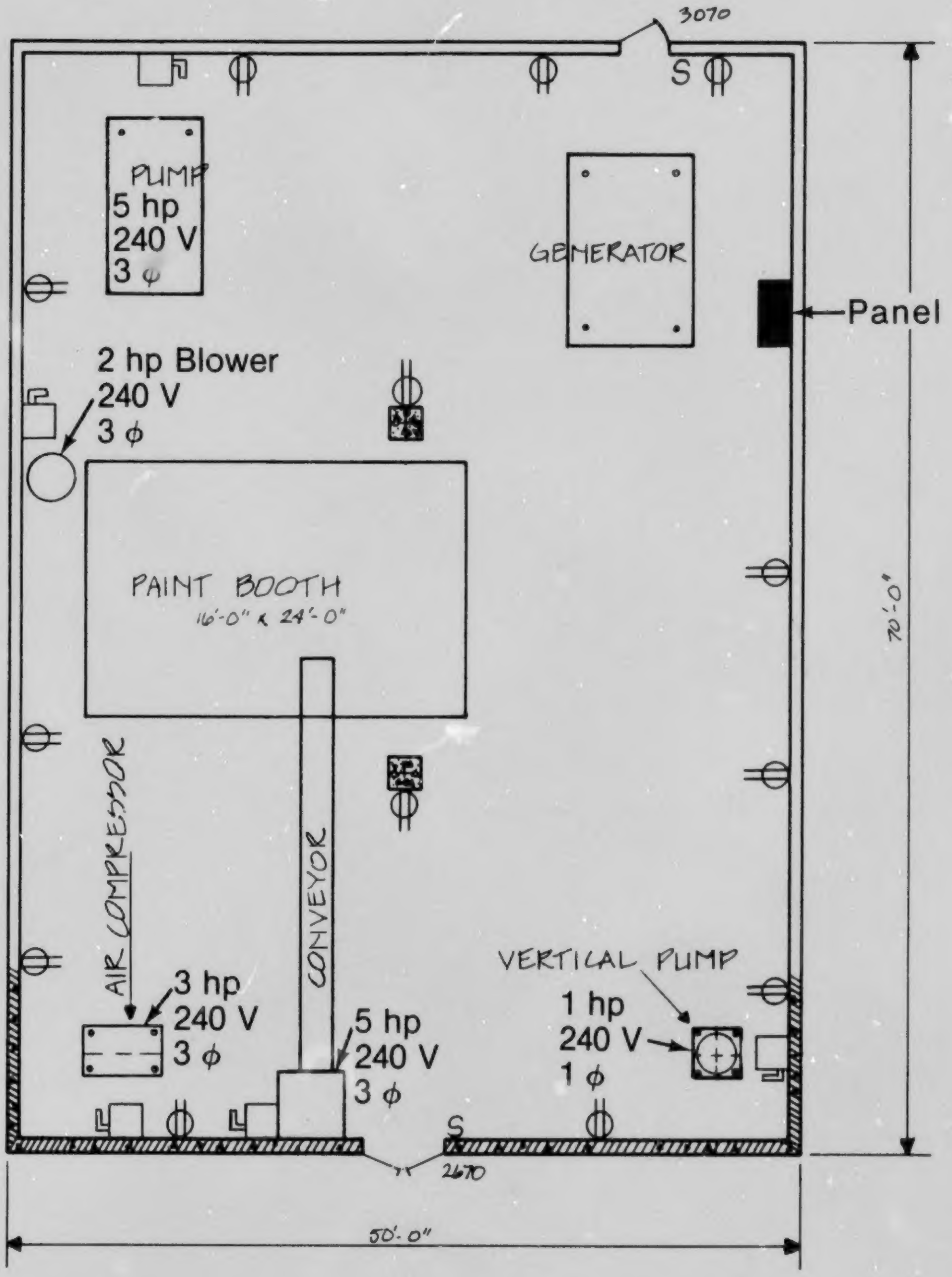
D. Convert measurement to feet if possible, and then add inches and fractions of an inch to obtain a correct measurement (Figure 11)

   EXAMPLE:

FIGURE 11



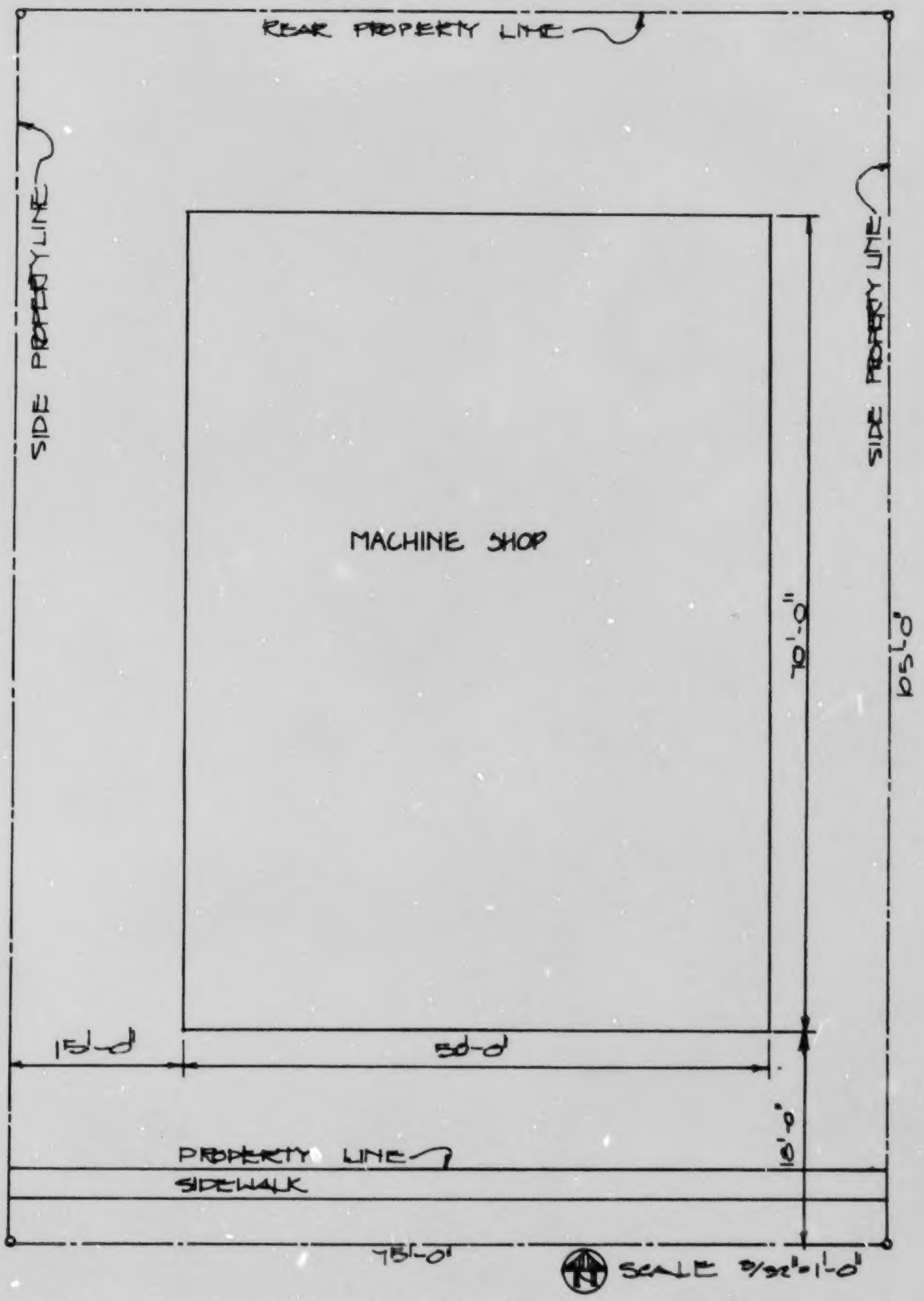
Electrical Floor Plan


3070
S
PUMP
5 hp
240 V
3 φ
GENERATOR
Panel
2 hp Blower
240 V
3 φ
PAINT BOOTH
16'-0" x 24'-0"
70'-0"
AIR COMPRESSOR
3 hp
240 V
3 φ
CONVEYOR
5 hp
240 V
3 φ
VERTICAL PUMP
1 hp
240 V
1 φ
S
2670
50'-0"

SCALE 3/32" = 1'-0"

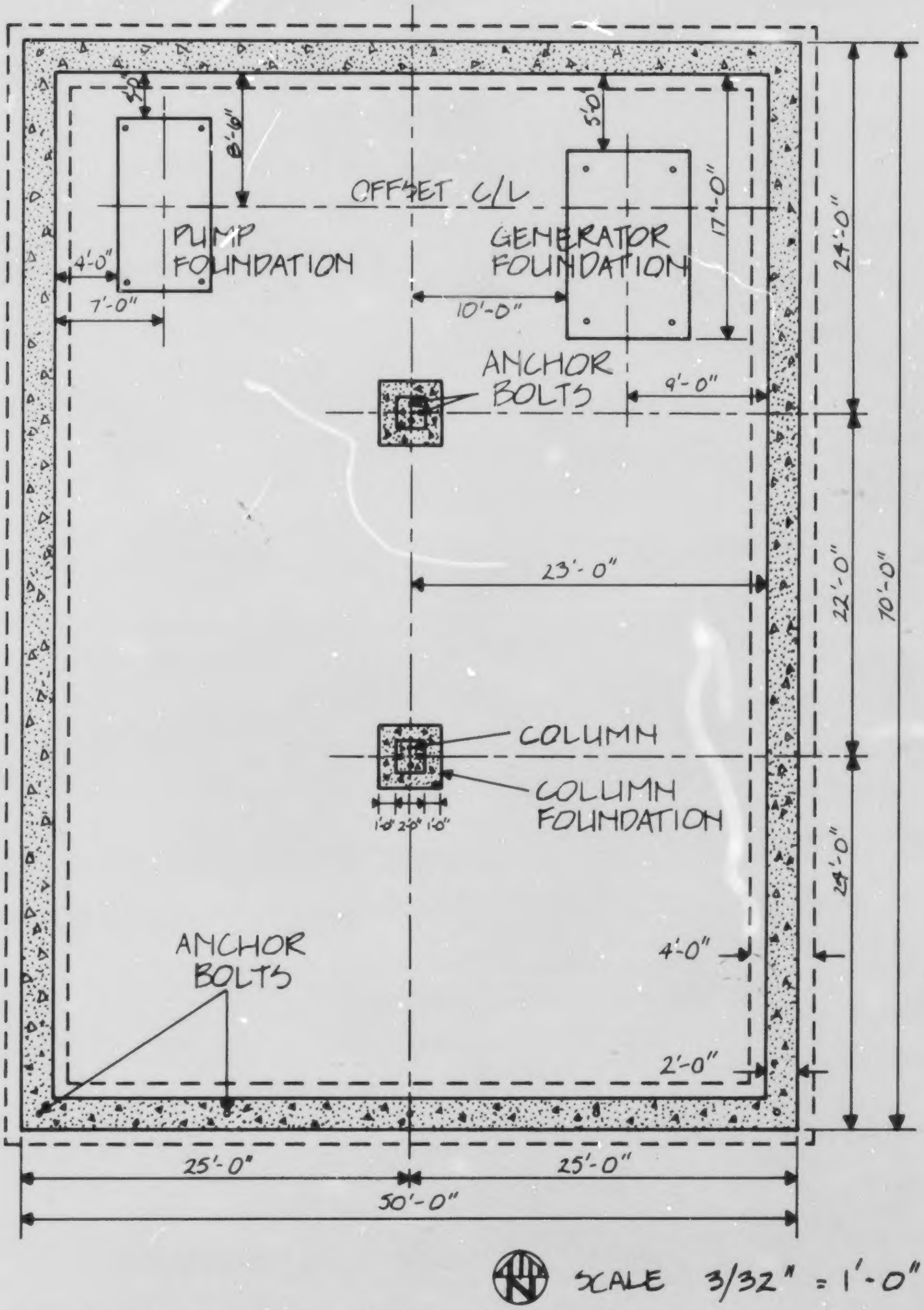
NOTE: Drawing was originally drawn to the scale shown. Drawing was reduced to fit page and can no longer be scaled.

Plot Plan


REAR PROPERTY LINE
SIDE PROPERTY LINE
SIDE PROPERTY LINE
MACHINE SHOP
70'-0"
105'-0"
15'-0"
50'-0"
10'-0"
PROPERTY LINE
SIDEWALK
75'-0"
N
SCALE 3/32"=1'-0"

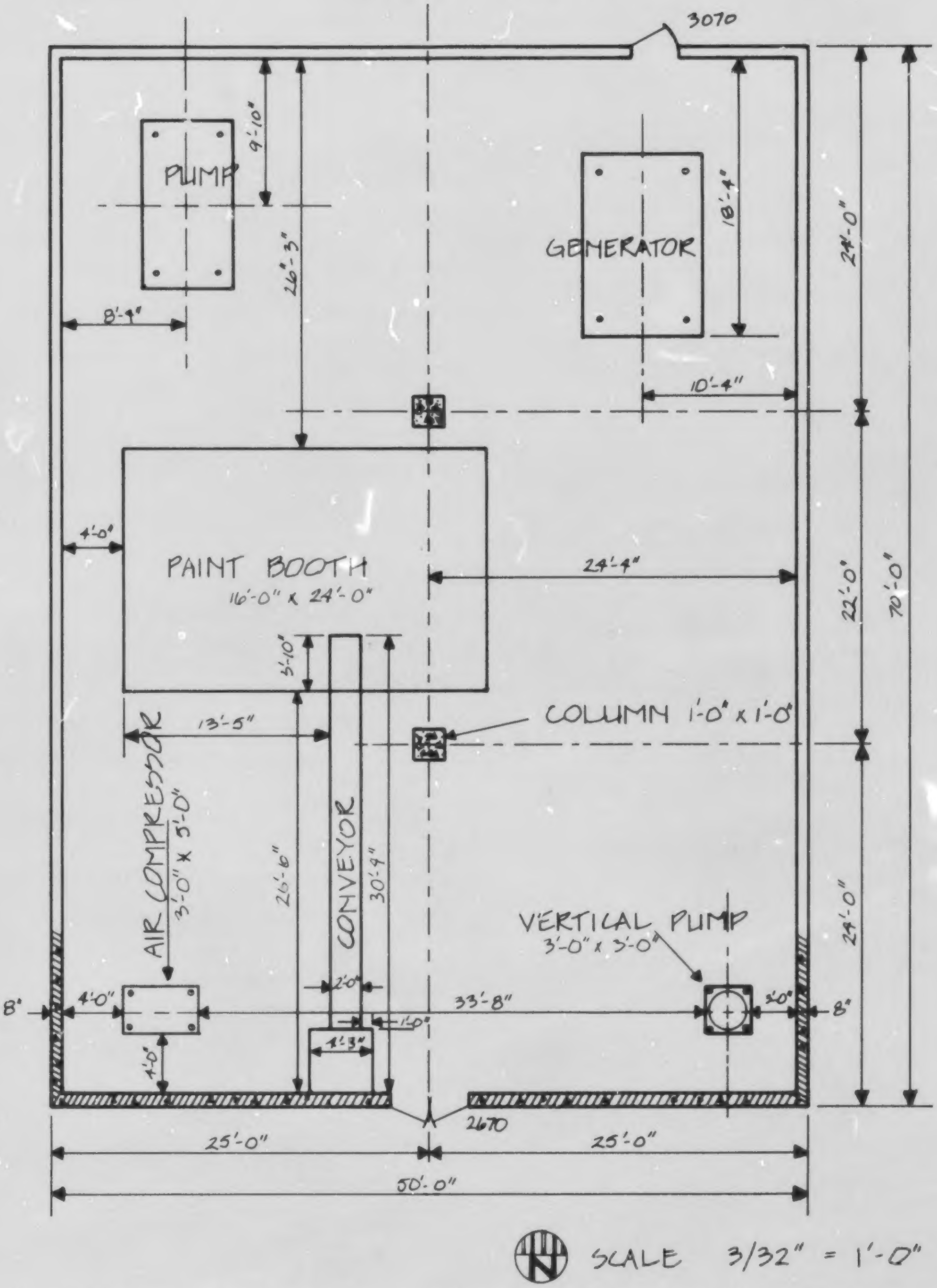
NOTE: Drawing was originally drawn to the scale shown. Drawing was reduced to fit page and can no longer be scaled.

Foundation Plan


5'-0"
8'-6"
5'-0"
OFFSET C/L
PUMP FOUNDATION
4'-0"
7'-0"
GENERATOR FOUNDATION
10'-0"
17'-0"
24'-0"
ANCHOR BOLTS
9'-0"
23'-0"
22'-0"
70'-0"
COLUMN
COLUMN FOUNDATION
1'-0" 2'-0" 1'-0"
24'-0"
ANCHOR BOLTS
4'-0"
2'-0"
25'-0"
25'-0"
50'-0"
N
SCALE 3/32" = 1'-0"

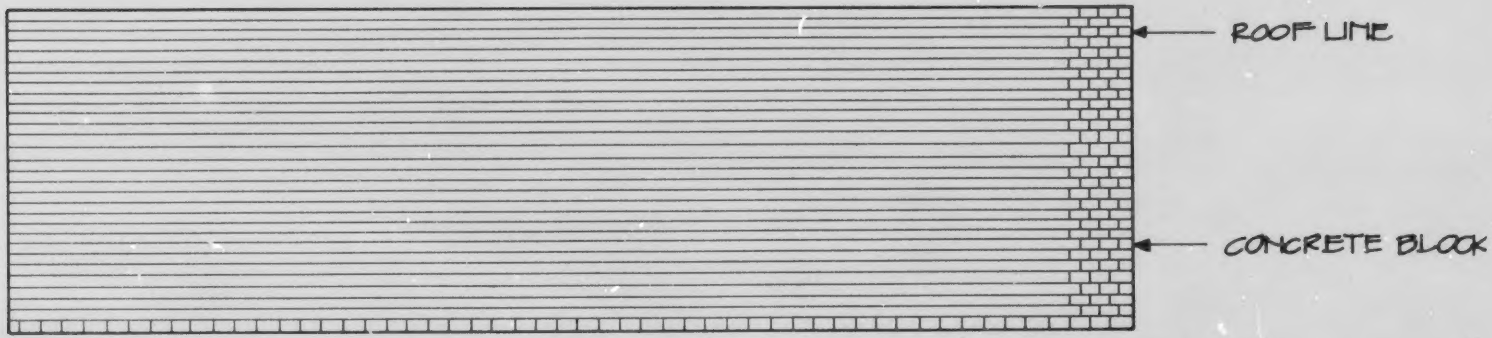
NOTE: Drawing was originally drawn to the scale shown. Drawing was reduced to fit page and can no longer be scaled.

Floor Plan

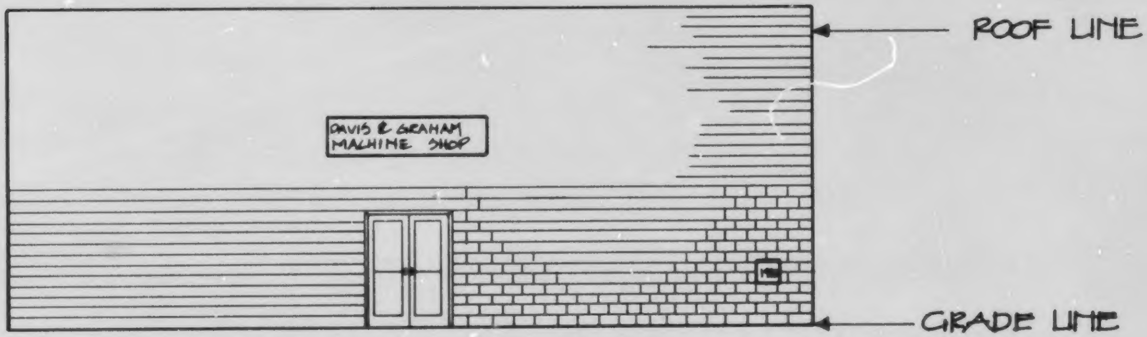

3070
PUMP
9'-10"
26'-3"
8'-4"
GENERATOR
18'-4"
24'-0"
10'-4"
4'-0"
PAINT BOOTH
16'-0" x 24'-0"
24'-4"
22'-0"
70'-0"
3'-10"
13'-5"
COLUMN 1'-0" x 1'-0"
AIR COMPRESSOR
3'-0" x 5'-0"
26'-6"
CONVEYOR
30'-4"
VERTICAL PUMP
3'-0" x 3'-0"
24'-0"
8"
4'-0"
2'-0"
33'-8"
3'-0"
8"
1'-0"
4'-3"
4'-0"
2670
25'-0"
25'-0"
50'-0"
N
SCALE 3/32" = 1'-0"

NOTE: Drawing was originally drawn to the scale shown. Drawing was reduced to fit page and can no longer be scaled.

Elevations

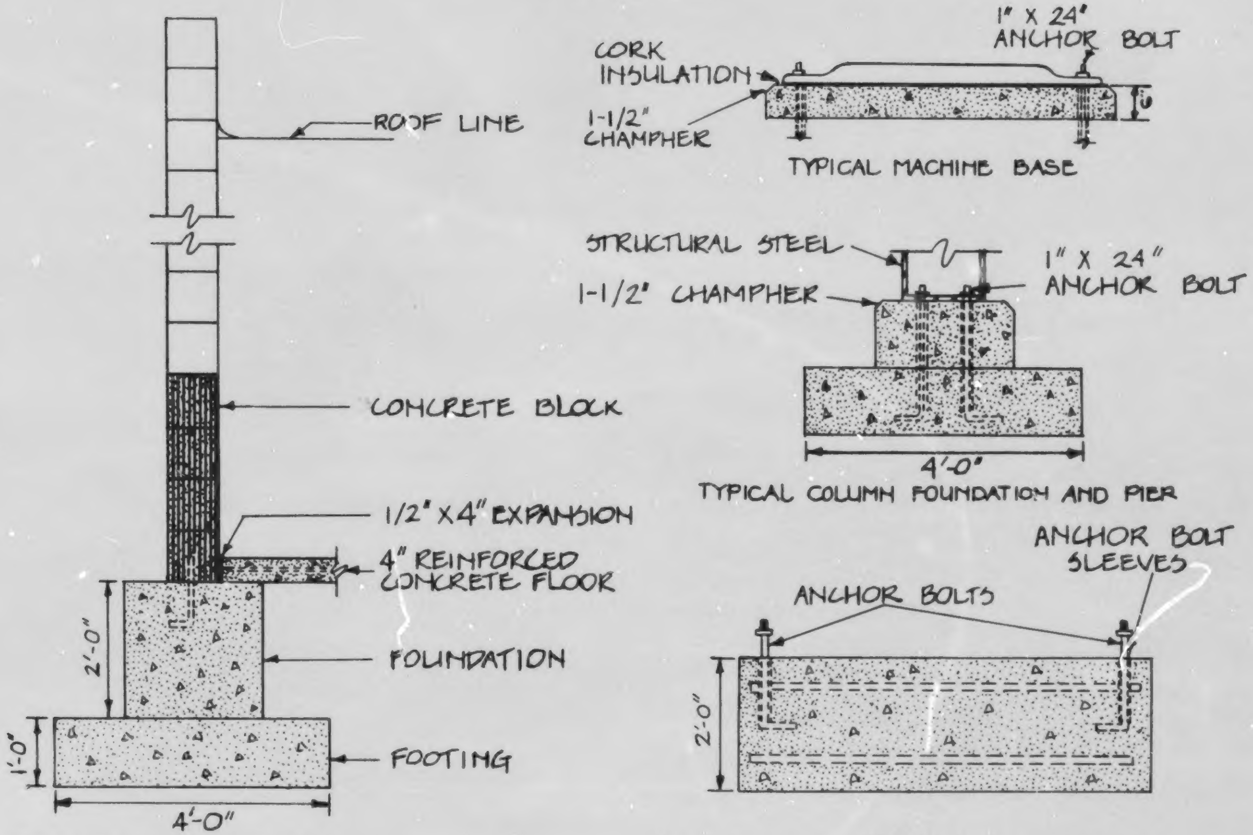

ROOF LINE
CONCRETE BLOCK

WEST ELEVATION


DAVIS & GRAHAM
MACHINE SHOP
ROOF LINE
GRADE LINE

SOUTH ELEVATION

Details


ROOF LINE
CONCRETE BLOCK
1/2" X 4" EXPANSION
4" REINFORCED CONCRETE FLOOR
FOUNDATION
FOOTING
2'-0"
1'-0"
4'-0"
CORK INSULATION
1-1/2" CHAMPHER
1" X 24" ANCHOR BOLT
6"
TYPICAL MACHINE BASE
STRUCTURAL STEEL
1-1/2" CHAMPHER
1" X 24" ANCHOR BOLT
4'-0"
TYPICAL COLUMN FOUNDATION AND PIER
ANCHOR BOLT SLEEVES
ANCHOR BOLTS
2'-0"

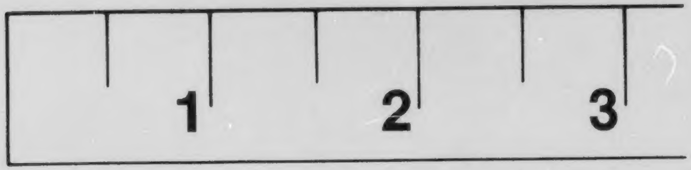
TYPICAL EXTERIOR WALL

TYPICAL MACHINE FOUNDATION

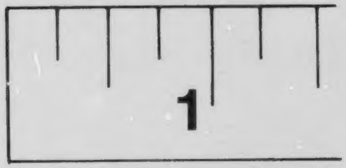
NOTE: Drawing was originally drawn to the scale shown. Drawing was reduced to fit page and can no longer be scaled.

Graduations on a Rule

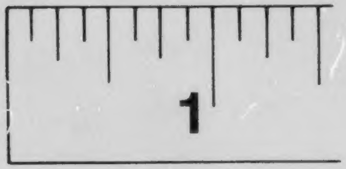
Halves



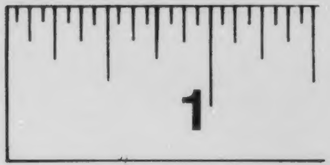
Quarters



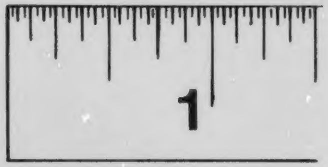
Eighths

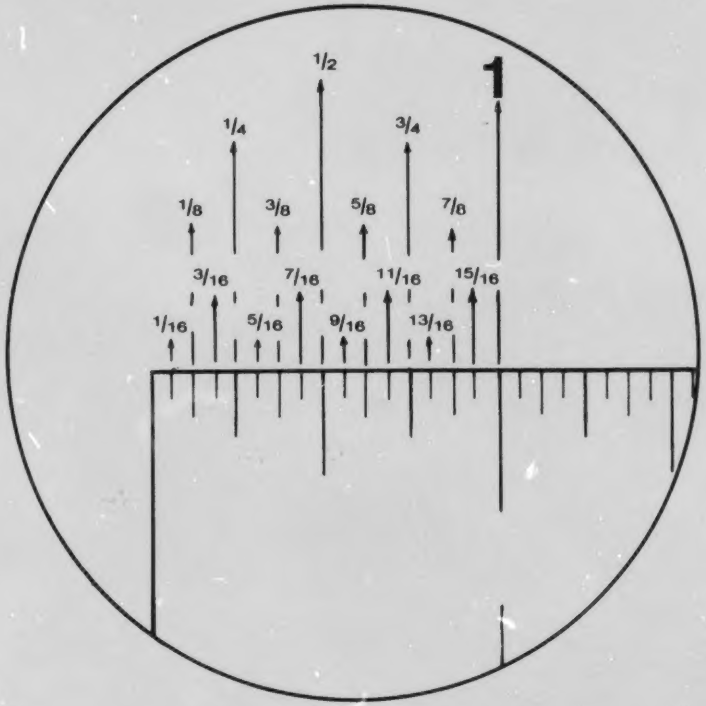


Sixteenths



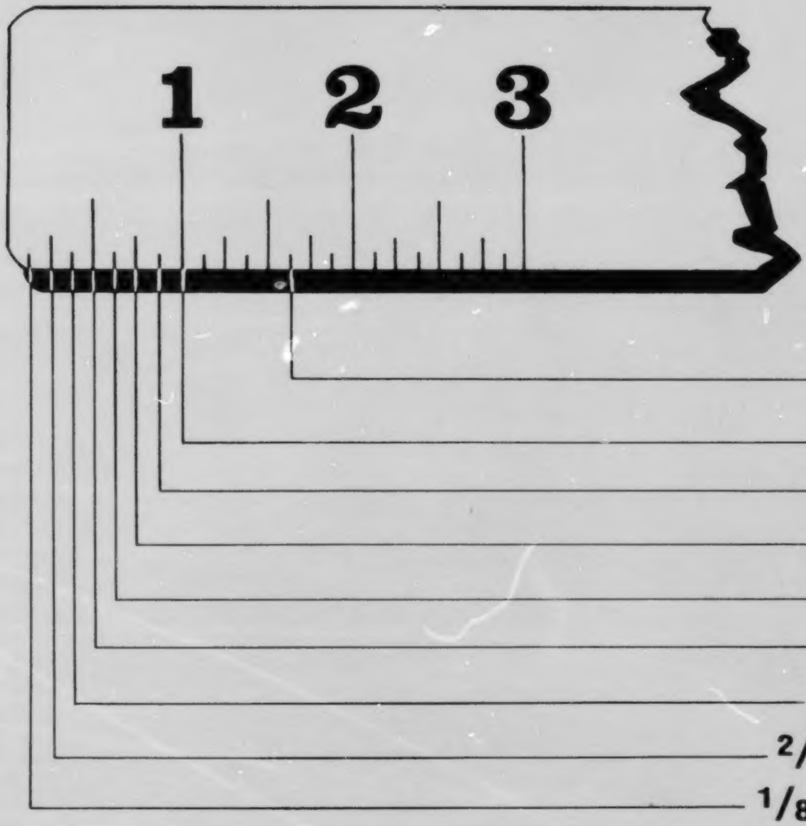
Thirty-Seconds




1/2
1
1/4
3/4
1/8
3/8
5/8
7/8
3/16
7/16
11/16
15/16
1/16
5/16
9/16
13/16

Graduations Applied to a Rule

Reading the Eighths Rule



13/8" = 1 5/8"

8/8" = 1"

7/8"

6/8" = 3/4"

5/8"

4/8" = 1/2"

3/8"

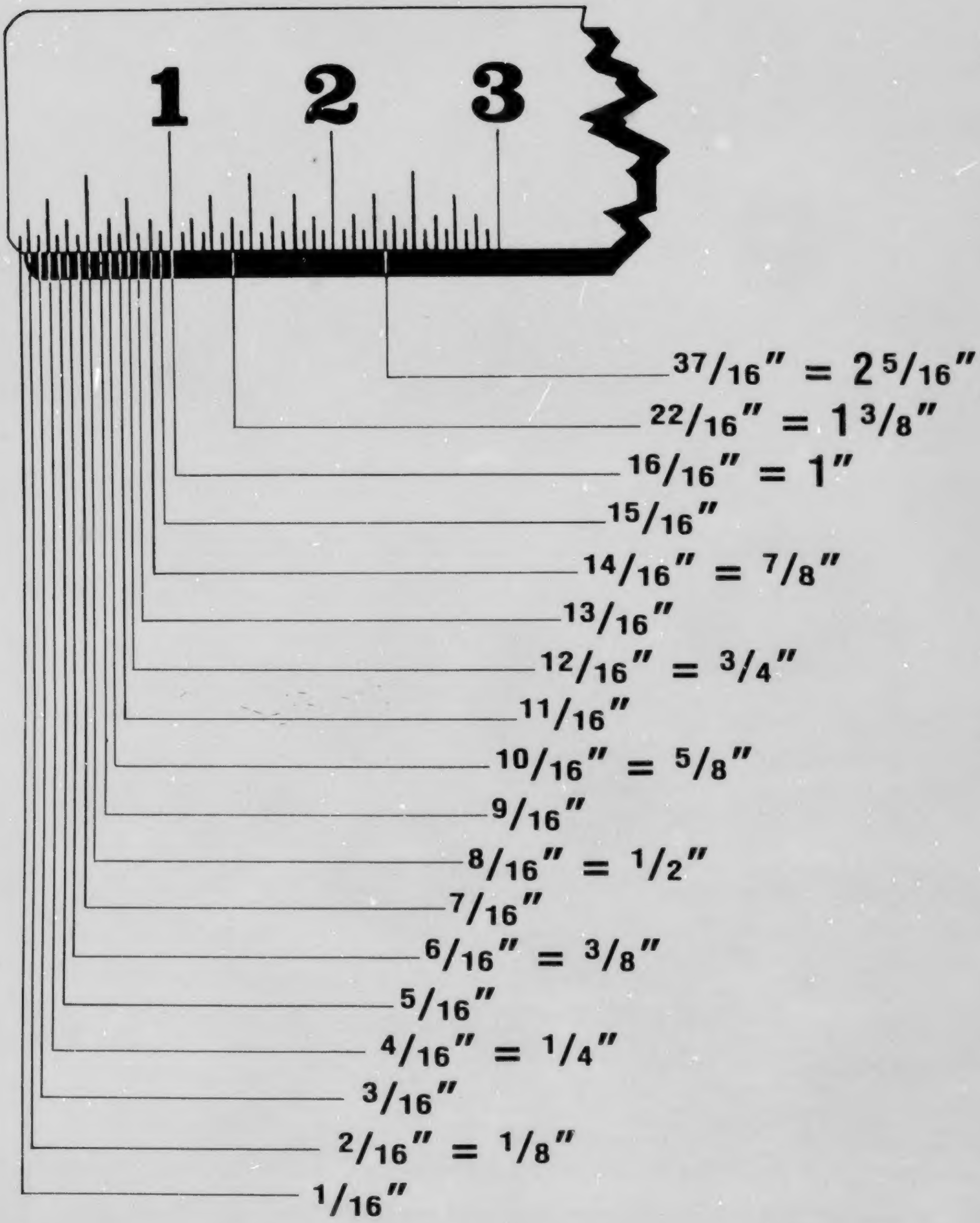
2/8" = 1/4"

1/8"

TM #8

IED - 121-A

Reading the Sixteenths Rule


1
2
3
37/16" = 2 5/16"
22/16" = 1 3/8"
16/16" = 1"
15/16"
14/16" = 7/8"
13/16"
12/16" = 3/4"
11/16"
10/16" = 5/8"
9/16"
8/16" = 1/2"
7/16"
6/16" = 3/8"
5/16"
4/16" = 1/4"
3/16"
2/16" = 1/8"
1/16"

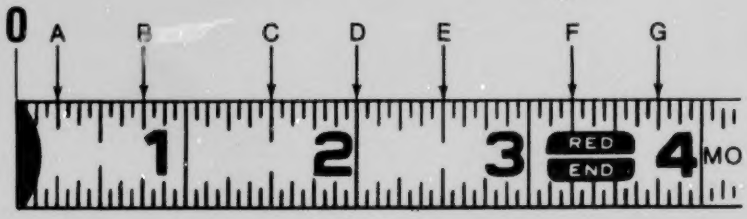
BLUEPRINT READING
UNIT III

ASSIGNMENT SHEET #1 — READ MEASUREMENTS ON A RULE

NAME ______________________________ SCORE ____________

Reading measurements on a rule is a basic skill required for reading blueprints. Technicians should practice this skill until they can quickly and accurately read all types of rules.

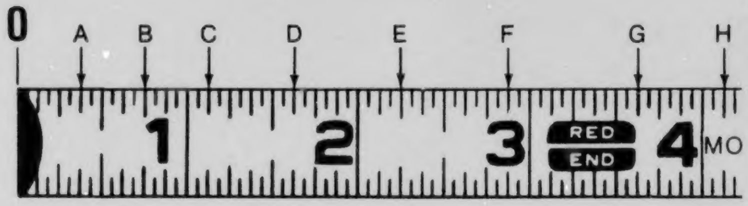
A. Read to the nearest ¼ inch the rule in the drawing below. Write your answers in the blanks provided. Reduce fractions where possible.



1. 0 to A = ____________
2. 0 to B = ____________
3. 0 to C = ____________
4. 0 to D = ____________
5. 0 to E = ____________
6. A to C = ____________
7. B to D = ____________
8. C to E = ____________
9. D to F = ____________
10. B to G = ____________

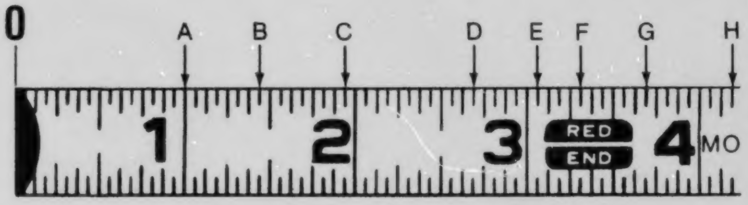
ASSIGNMENT SHEET #1

B. Read to the nearest 1/8 inch the rule in the drawing below. Write your answers in the blanks provided. Reduce fractions where possible.


0
A
B
C
D
E
F
G
H
1
2
3
RED
END
4
MO

1. 0 to A = ____________________
2. 0 to B = ____________________
3. 0 to C = ____________________
4. 0 to D = ____________________
5. 0 to E = ____________________
6. A to D = ____________________
7. C to F = ____________________
8. B to E = ____________________
9. E to H = ____________________
10. G to H = ____________________

C. Read to the nearest 1/16 inch the rule in the drawing below. Write your answers in the blanks provided. Reduce fractions where possible.


0
A
B
C
D
E
F
G
H
1
2
3
RED
END
4
MO

1. 0 to A = ____________________
2. 0 to B = ____________________
3. 0 to C = ____________________
4. 0 to D = ____________________
5. A to E = ____________________
6. B to F = ____________________
7. C to E = ____________________
8. D to F = ____________________
9. G to H = ____________________
10. C to H = ____________________

BLUEPRINT READING
UNIT III

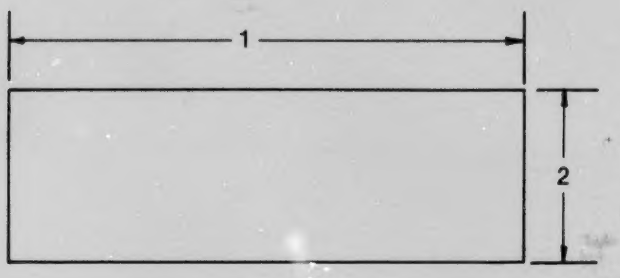
ASSIGNMENT SHEET #2 — USE A RULE TO MEASURE OBJECTS

NAME ____ SCORE ________________

Measuring objects provides practice in reading and using a rule. Technicians should practice this skill until they can quickly and accurately measure various objects.

Using a rule graduated to 1/16 of an inch, measure the following objects.

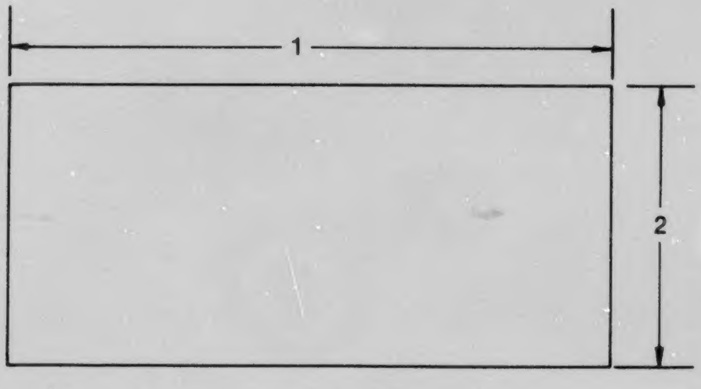
A.



1. Length = ________________

2. Height = ________________

B.

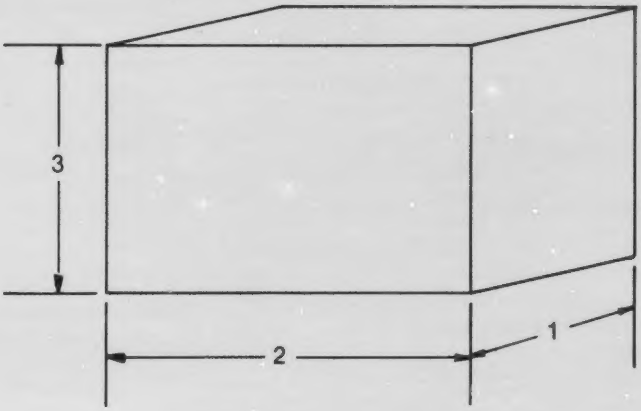


1. Length = ________________

2. Height = ________________

ASSIGNMENT SHEET #2

C.

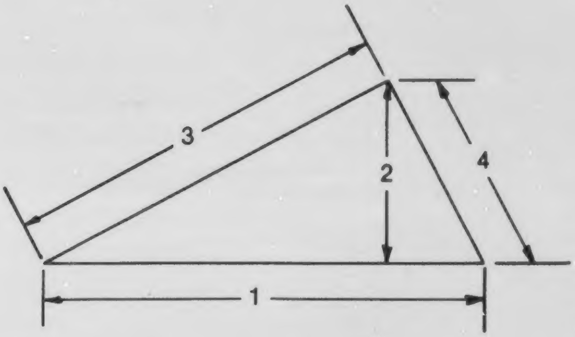


1. Width = ________________

2. Length = ________________

3. Height = ________________

D.



1. Base = ________________

2. Height = ________________

3. Slope c = ________________

4. Slope d = ________________

BLUEPRINT READING
UNIT III

ASSIGNMENT SHEET #3 — CIRCUIT A PRINT

NAME ______________________________ SCORE ______________

This assignment sheet is the first step in determining the location of conduit runs, and is designed to help the electrical technician plan an electrical wiring job.

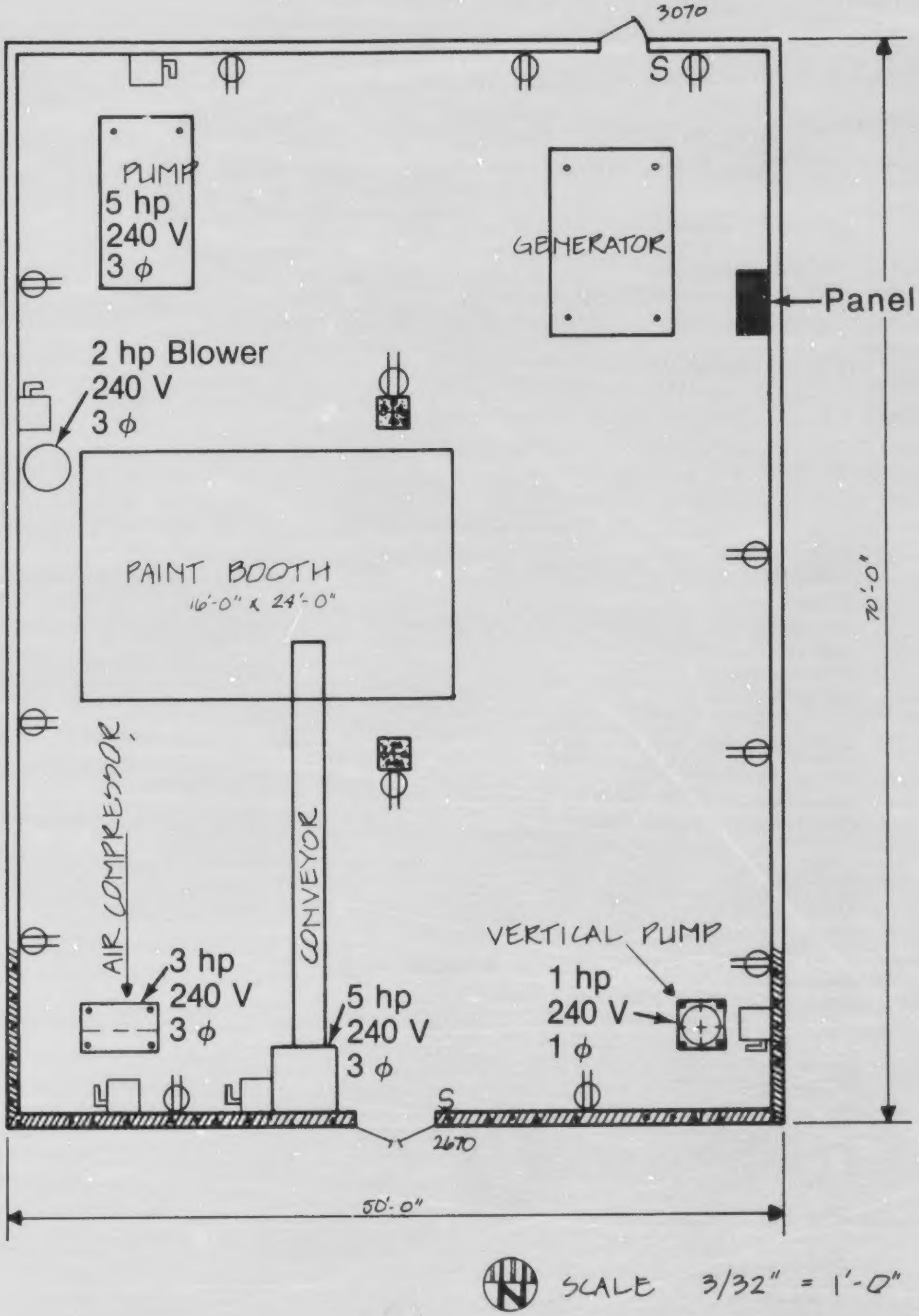
PART I

Using the blueprint on the following page and referring to Information Sheet, Section VI, lay out the conduit runs needed to connect all electrical equipment to the main power panel. Several standard duplex receptacles may be run in one conduit.

Have your instructor check your work before proceeding to PART II.

ASSIGNMENT SHEET #3

Floor Plan


3070
PUMP
5 hp
240 V
3 ϕ
S
GENERATOR
Panel
2 hp Blower
240 V
3 ϕ
PAINT BOOTH
16'-0" x 24'-0"
70'-0"
AIR COMPRESSOR
CONVEYOR
3 hp
240 V
3 ϕ
5 hp
240 V
3 ϕ
VERTICAL PUMP
1 hp
240 V
1 ϕ
S
2670
50'-0"
N
SCALE 3/32" = 1'-0"

ASSIGNMENT SHEET #3

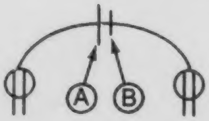
PART II

The electrical technician must be able to determine the number of wires in a conduit run in order to select the proper size conduit.

Mark the blueprint containing your answers to Part I to indicate the proper number of wires for each conduit run. Refer to Information Sheet, Section VI and the example below if needed.

Have your instructor check your work before proceeding to Assignment Sheet #4.

EXAMPLE:



A. Each long mark across conduit line indicates one hot conductor to be installed in the conduit run.

B. Each short mark across conduit line indicates one neutral conductor or equipment grounding wire.

BLUEPRINT READING
UNIT III

ASSIGNMENT SHEET #4 — DETERMINE WIRE SIZES FOR BLUEPRINT CONDUIT RUNS

NAME ______________________________ SCORE ______________

The *National Electrical Code* requires that specific wire sizes be used for certain current ratings; therefore, it is important that the electrical technician be able to determine wire size according to the *Code*.

Use the blueprint from Assignment Sheet #3 and the information below to determine wire size for each conduit run. Write the correct sizes on the blueprint. You may refer to Information Sheet, Section VII if needed.

A. The specification sheet calls for #12 THHN wire to be used in receptacle circuits, and another specification sheet calls for THW to be used on main service and motor circuits.

B. Refer to *National Electrical Code,* Article 430-148 for full-load amperes for single-phase motors; refer to Article 430-150 for full-load amperes for three-phase motors.

C. Refer to *National Electrical Code,* Article 430-22 for single-motor circuits.

D. Refer to *National Electrical Code,* Article 310-16 for current-carrying capacity of wires.

BLUEPRINT READING
UNIT III

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 1. $^{1}/_{4}$ inch
2. $^{3}/_{4}$ inch
3. 1 $^{1}/_{2}$ inch
4. 2 inches
5. 2 $^{1}/_{2}$ inches
6. 1 $^{1}/_{4}$ inches
7. 1 $^{1}/_{4}$ inches
8. 1 inch
9. 1 $^{1}/_{4}$ inches
10. 3 inches

B. 1. $^{3}/_{8}$ inch
2. $^{3}/_{4}$ inch
3. 1 $^{1}/_{8}$ inches
4. 1 $^{5}/_{8}$ inches
5. 2 $^{1}/_{4}$ inches
6. 1 $^{1}/_{4}$ inches
7. 1 $^{3}/_{4}$ inches
8. 1 $^{1}/_{2}$ inches
9. 1 $^{7}/_{8}$ inches
10. $^{1}/_{2}$ inch

C. 1. 1 inch
2. 1 $^{7}/_{16}$ inches
3. 1 $^{15}/_{16}$ inches
4. 2 $^{11}/_{16}$ inches
5. 2 $^{1}/_{16}$ inches
6. 1 $^{7}/_{8}$ inches
7. 1 $^{1}/_{8}$ inches
8. $^{5}/_{8}$ inch
9. $^{1}/_{2}$ inch
10. 2 $^{1}/_{4}$ inches

Assignment Sheet #2

A. 1. 3 inches
2. 1 inch

ANSWERS TO ASSIGNMENT SHEETS

B.
1. 3 1/2 inches
2. 1 5/8 inches

C.
1. 1 inch
2. 2 1/8 inches
3. 1 7/16 inches

D.
1. 2 9/16 inches
2. 1 1/16 inches
3. 2 1/4 inches
4. 1 3/16 inches

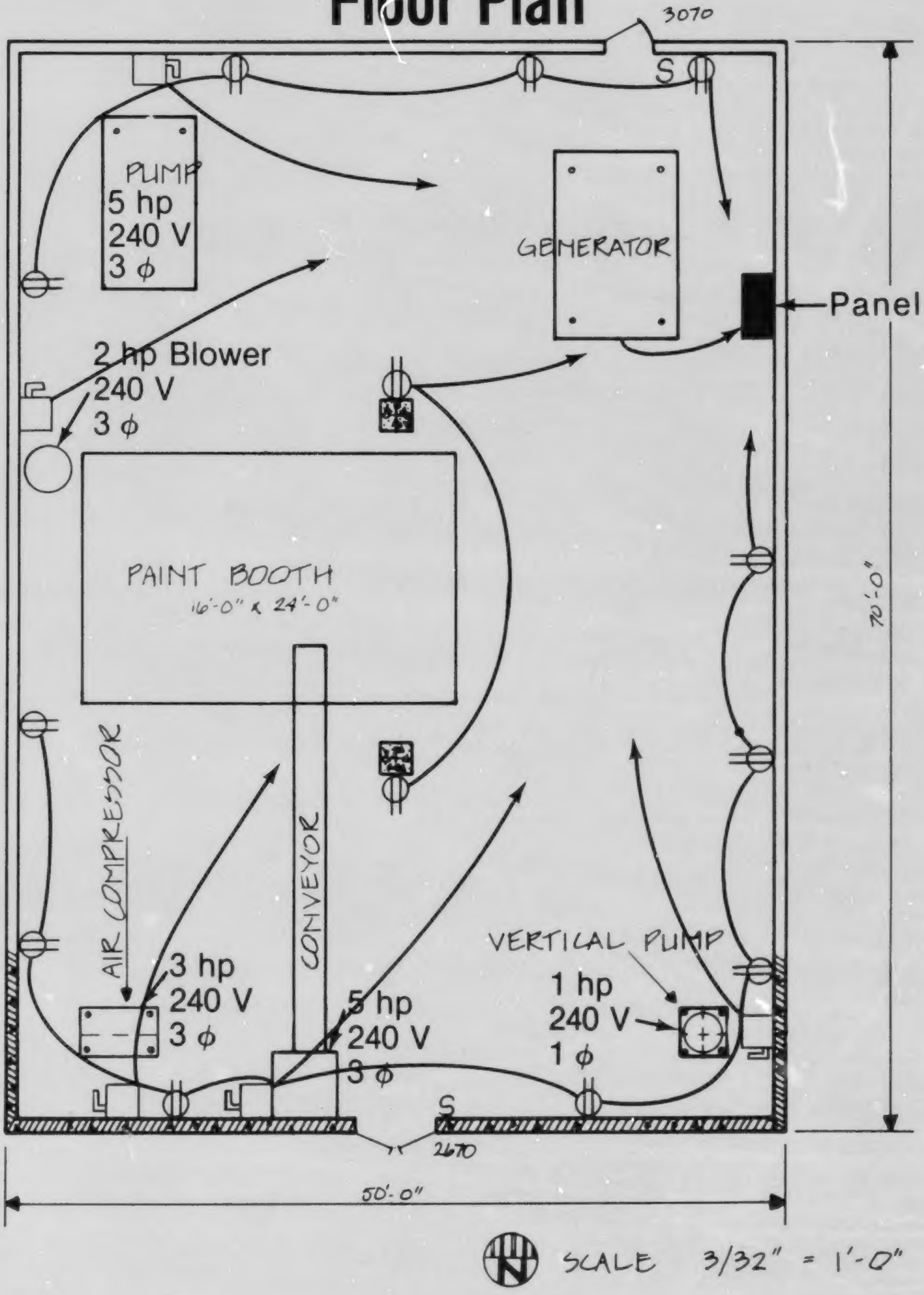
Assignment Sheets #3 and #4 — See following pages.

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #3

PART I

Floor Plan

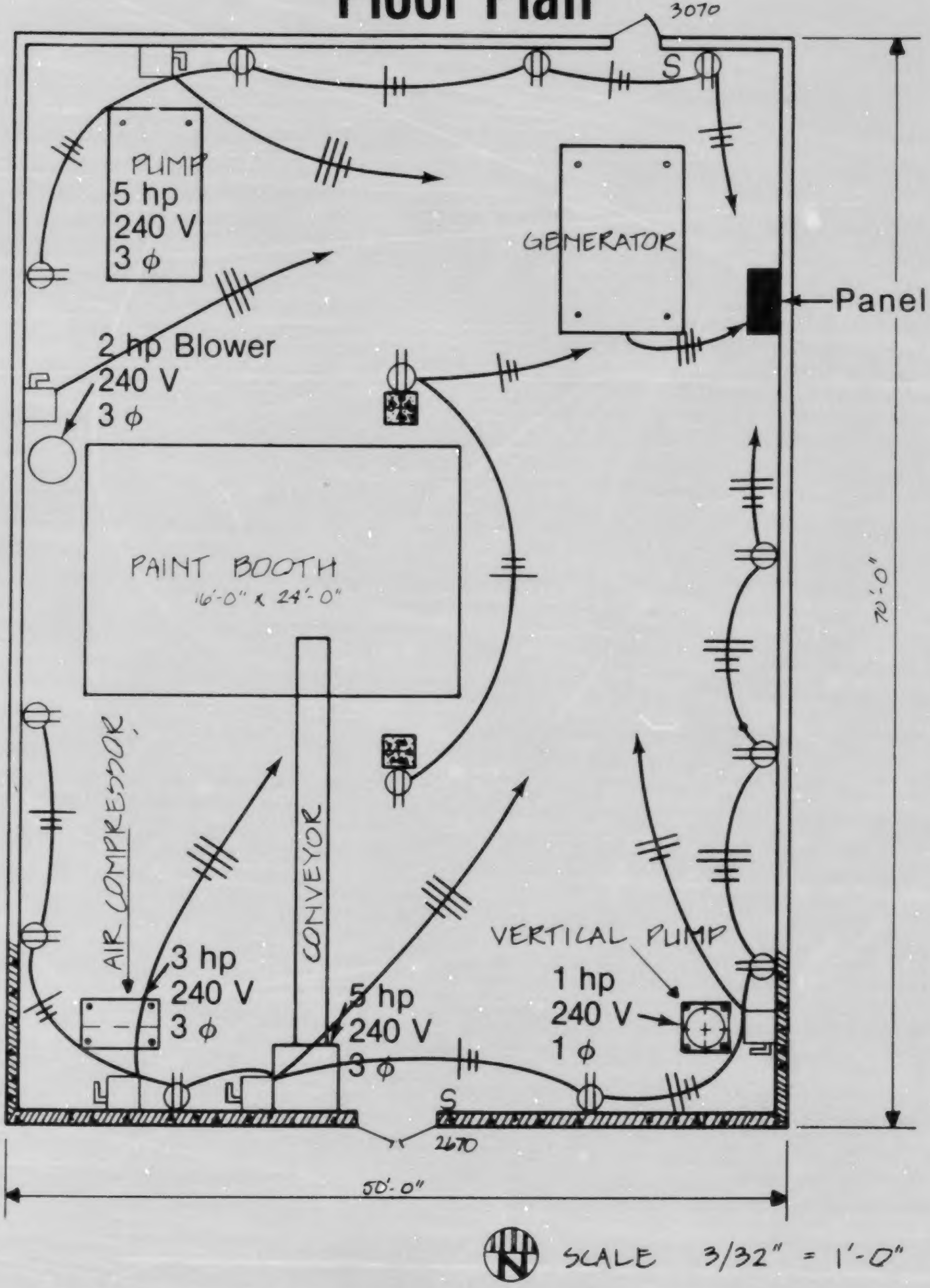

3070
PUMP
5 hp
240 V
3 ϕ
GENERATOR
Panel
2 hp Blower
240 V
3 ϕ
PAINT BOOTH
16'-0" x 24'-0"
70'-0"
AIR COMPRESSOR
CONVEYOR
3 hp
240 V
3 ϕ
5 hp
240 V
3 ϕ
VERTICAL PUMP
1 hp
240 V
1 ϕ
S
S
2670
50'-0"
SCALE 3/32" = 1'-0"

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #3

PART II

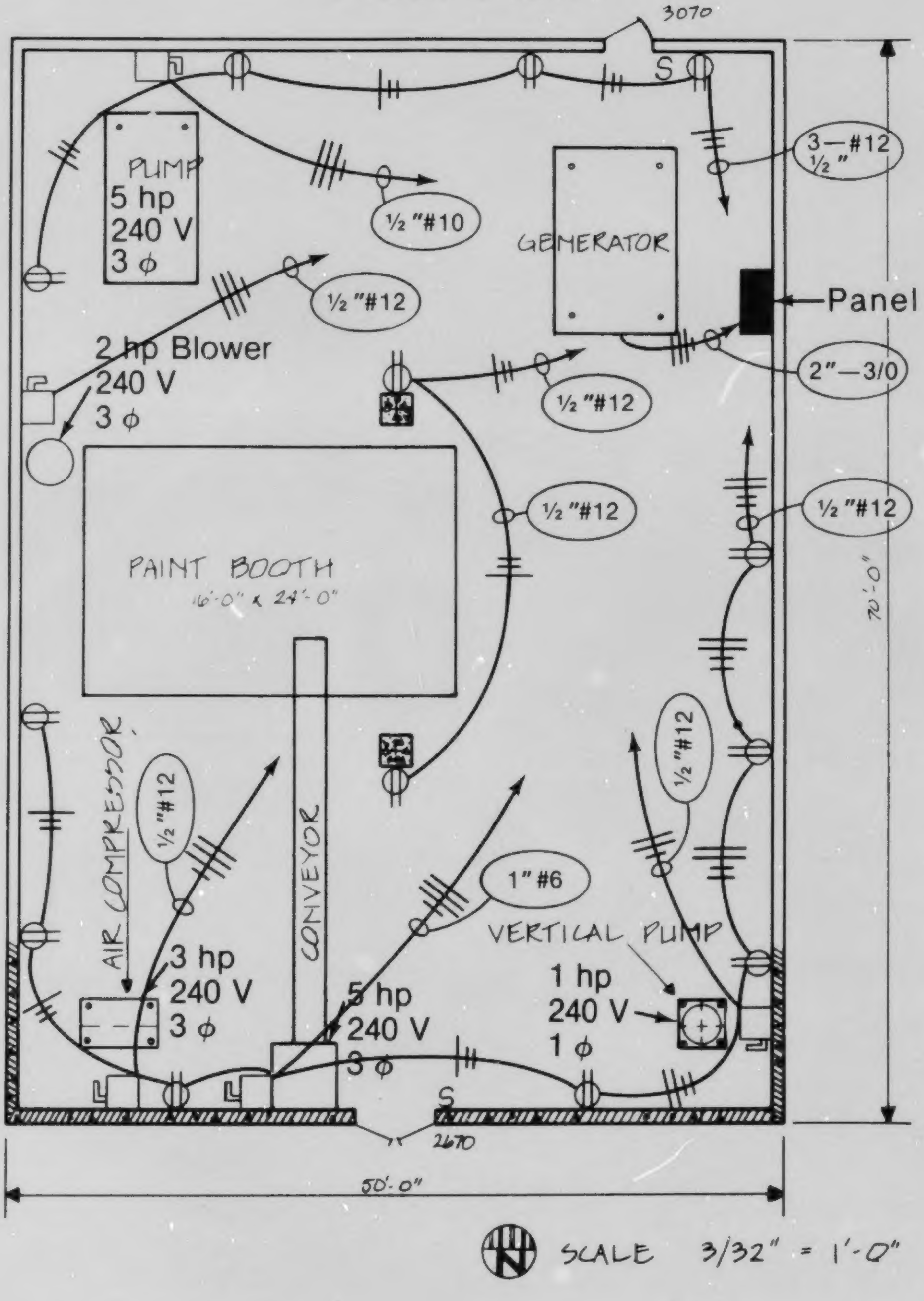
Floor Plan


3070
S
PUMP
5 hp
240 V
3 ϕ
GENERATOR
Panel
2 hp Blower
240 V
3 ϕ
PAINT BOOTH
16'-0" x 24'-0"
70'-0"
AIR COMPRESSOR
CONVEYOR
3 hp
240 V
3 ϕ
5 hp
240 V
3 ϕ
VERTICAL PUMP
1 hp
240 V
1 ϕ
S
2670
50'-0"
N
SCALE 3/32" = 1'-0"

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #4

Floor Plan


3070
S
3—#12
½ "
½ "#10
PUMP
5 hp
240 V
3 ϕ
GENERATOR
Panel
½ "#12
2 hp Blower
240 V
3 ϕ
2"—3/0
½ "#12
½ "#12
½ "#12
PAINT BOOTH
16'-0" x 24'-0"
70'-0"
AIR COMPRESSOR
½ "#12
CONVEYOR
½ "#12
1" #6
VERTICAL PUMP
3 hp
240 V
3 ϕ
5 hp
240 V
3 ϕ
1 hp
240 V
1 ϕ
S
2670
50'-0"
N
SCALE 3/32" = 1'-0"

BLUEPRINT READING
UNIT III

TEST

NAME ____ SCORE ________________

1. Match to their correct definitions terms associated with blueprint reading. Write the correct numbers in the blanks.

______a. Process of installing outlet boxes, breaker panel, conduit, pulling wire, and grounding connections

______b. Process of installing, energizing, and testing all circuits, switches, receptacles, and fixtures; and connecting and testing motors and equipment, leaving them ready for use

______c. To mark a blueprint with lines and symbols to help determine number of circuits, amount and sizes of wires, amount and sizes of conduit, and number and sizes of boxes needed

______d. Taking information from a circuited blueprint and converting it to a supply list

______e. Process of making all splices and connections, leaving the job ready for other tradespeople such as insulators, sheetrockers, and painters

______f. Conduit and wire that runs between breaker panel and first outlet or junction box on that circuit or circuits

______g. To convert takeoff list into an order form that includes catalog numbers for purchasing materials and supplies

1. Takeoff
2. Home run
3. Rough-in
4. Make-up
5. Circuit a print
6. Make requisition
7. Trim-out

2. List information commonly found on electrical blueprints.

a. ____

b. ____

c. ____

d. ____

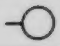
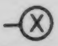
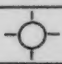
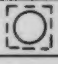
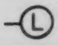
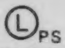
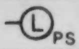
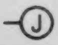
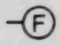
e. ____

f. ____

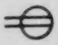
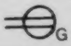
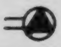
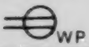
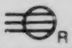
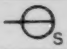
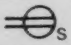
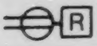
TEST

3. Name electrical blueprint symbols illustrated in the following charts.

a. General outlets

Type	Symbol	
	Ceiling	Wall
1)____________________		
2)____________________		
3)____________________		
4)____________________		
5)____________________		
6)____________________		
7)____________________		
8)____________________		
9)____________________		

b. Convenience outlets

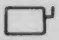
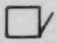
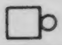
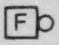
Type	Symbol
1)____________________	
2)____________________	
3)____________________	
4)____________________	
5)____________________	
6)____________________	
7)____________________	
8)____________________	
9)____________________	
10)___________________	

TEST

c. Switch outlets

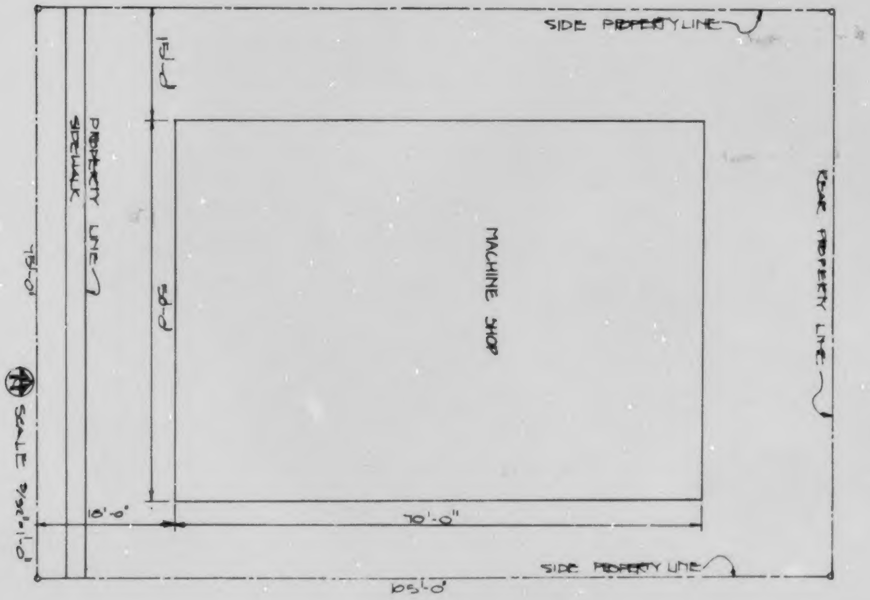
Type	Symbol
1) ______________________	S
2) ______________________	S_2
3) ______________________	S_3
4) ______________________	S_4
5) ______________________	S_P
6) ______________________	S_{WP}
7) ______________________	S_F

d. Panels, circuits, auxiliary, and miscellaneous

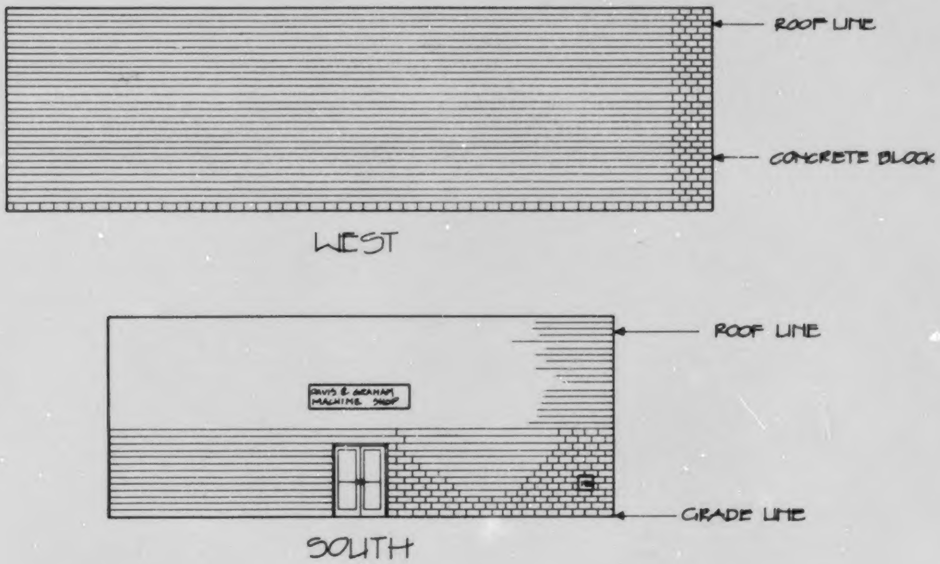
Type	Symbol
1) ______________________	Ⓣ or $\boxed{Th}$
2) ______________________	▬
3) ______________________	▨
4) ______________________	⊠
5) ______________________	
6) ______________________	-----
7) ______________________	—·—
8) ______________________	——
9) ______________________	—·—·—
10) ______________________	⊡
11) ______________________	
12) ______________________	
13) ______________________	
14) ______________________	$\boxed{FS}$
15) ______________________	□

TEST

4. Label the following types of blueprints. Write the correct names in the blanks.

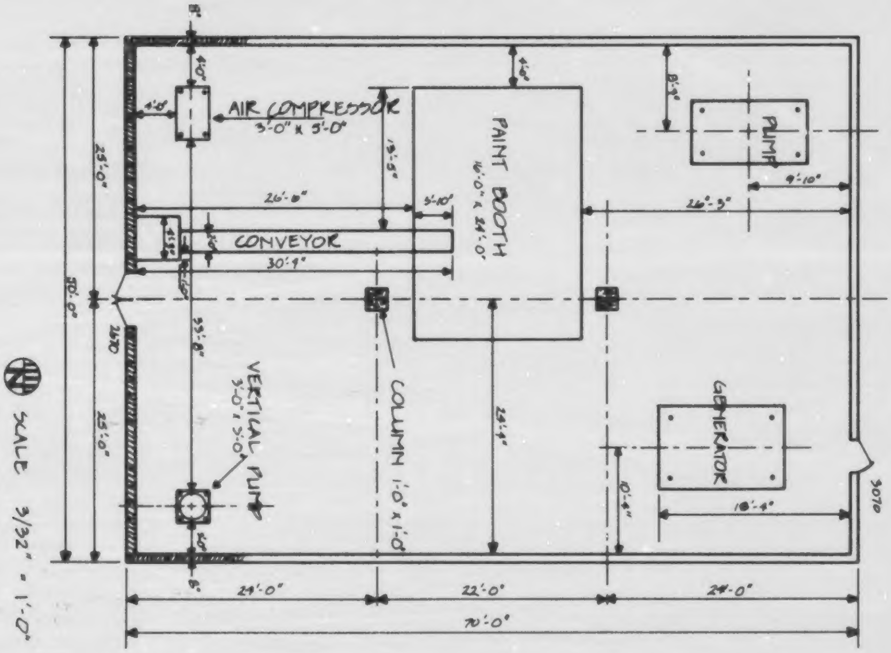

SIDE PROPERTY LINE
15'-0"
PROPERTY LINE
SIDEWALK
75'-0"
50'-0"
MACHINE SHOP
REAR PROPERTY LINE
N
SCALE 3/32"=1'-0"
10'-0"
70'-0"
SIDE PROPERTY LINE
105'-0"

a. ______________________________

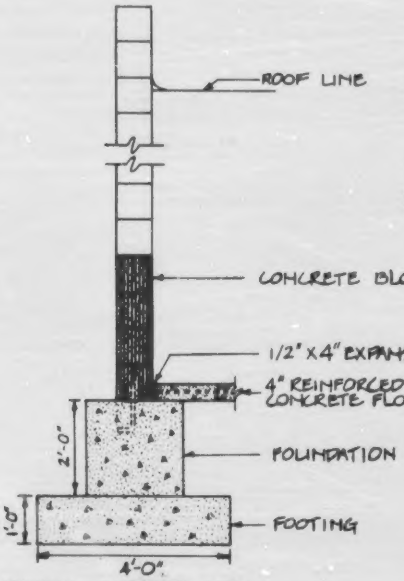

ROOF LINE
CONCRETE BLOCK
WEST
ROOF LINE
DAVIS & GRAHAM MACHINE SHOP
GRADE LINE
SOUTH

b. ______________________________

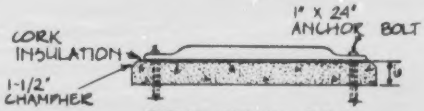
TEST


AIR COMPRESSOR
3'-0" x 5'-0"
PAINT BOOTH
16'-0" x 24'-0"
PUMP
CONVEYOR
30'-9"
26'-8"
5'-10"
26'-3"
9'-10"
15'-5"
4'-0"
8'-9"
25'-0"
50'-0"
3070
VERTICAL PUMP
3'-0" x 3'-0"
COLUMN 1'-0" x 1'-0"
23'-4"
GENERATOR
10'-4"
18'-4"
8"
24'-0"
22'-0"
24'-0"
70'-0"
N
SCALE 3/32" = 1'-0"

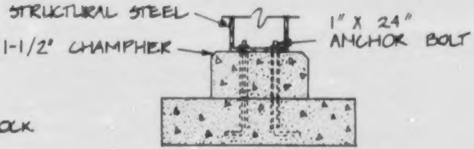
c. ______________________________


ROOF LINE
CONCRETE BLOCK
1/2" X 4" EXPANSION
4" REINFORCED CONCRETE FLOOR
FOUNDATION
FOOTING
2'-0"
1'-0"
4'-0"

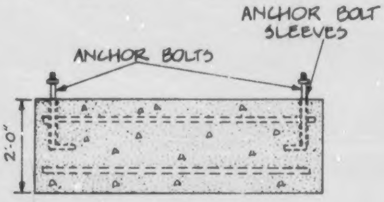
TYPICAL EXTERIOR WALL


CORK INSULATION
1" X 24" ANCHOR BOLT
1-1/2" CHAMPHER

TYPICAL MACHINE BASE


STRUCTURAL STEEL
1-1/2" CHAMPHER
1" X 24" ANCHOR BOLT
4'-0"

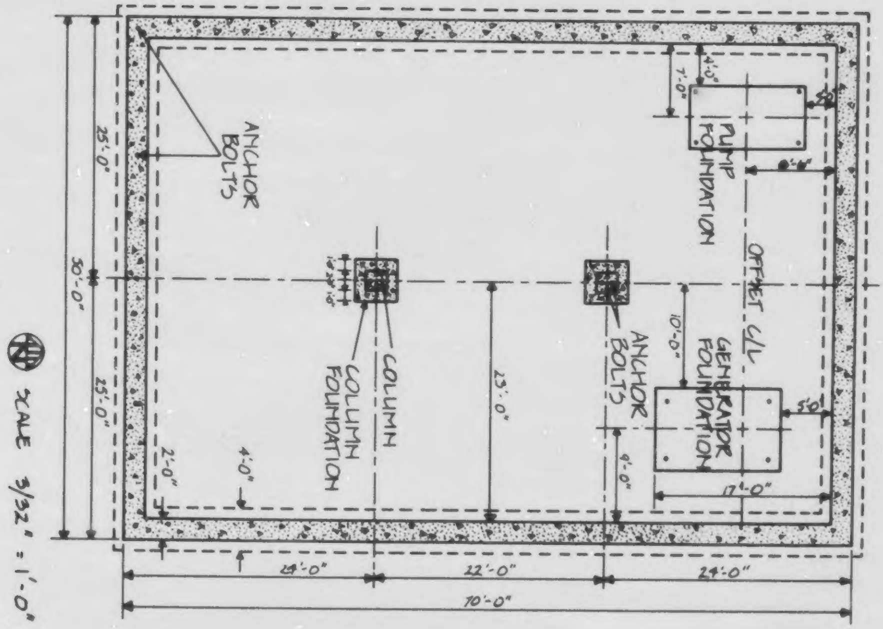
TYPICAL COLUMN FOUNDATION AND PIER


ANCHOR BOLTS
ANCHOR BOLT SLEEVES
2'-0"

TYPICAL MACHINE FOUNDATION

d. ______________________________

TEST


ANCHOR BOLTS
PUMP FOUNDATION
OFFSET C/L
GENERATOR FOUNDATION
ANCHOR BOLTS
COLUMN
COLUMN FOUNDATION
SCALE 3/32" = 1'-0"
25'-0"
50'-0"
25'-0"
2'-0"
4'-0"
23'-0"
10'-0"
4'-0"
7'-0"
4'-0"
5'-0"
8'-6"
17'-0"
24'-0"
22'-0"
24'-0"
70'-0"

e. ____

5. List typical electrical specifications for bidding.

a. ____

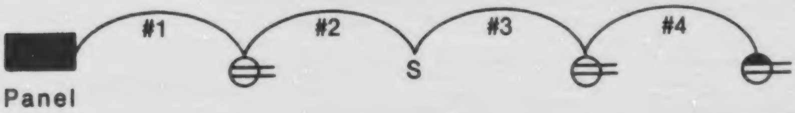
b. ____

c. ____

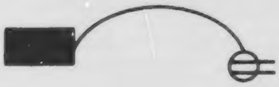
d. ____

TEST

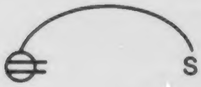
6. Circuit a print. List the types of wires required to serve each run. List each wire separately.



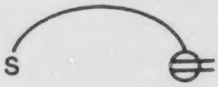
a. Run #1



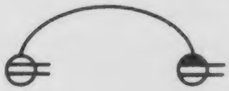
b. Run #2



c. Run #3



d. Run #4



TEST

7. Arrange in order the steps for determining motor-circuit wire sizes. Write a "1" before the first step, a "2" before the second step, and so on.

______a. Determine circuit ampacity from *NEC* Article 430-22 (continuous-duty motors)

______b. Determine wire size from *NEC* Table 310-16

______c. Determine motor size, voltage, and phase from print

______d. Determine full-load amperes from *NEC* Articles 430-148 and 430-150

______e. Determine wire insulation type, using *NEC* Table 310-13

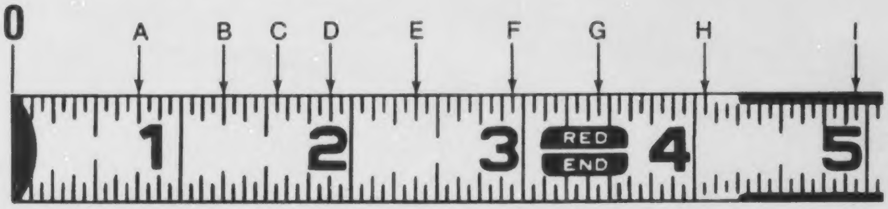
8. State steps for determining conduit size.

a. ______________________________

b. ______________________________

c. ______________________________

9. Read to the nearest 1/16 inch measurements on the standard rule illustrated below. Reduce answers where possible.



a. 0 to H = ______________

b. A to D = ______________

c. B to F = ______________

d. C to I = ______________

e. A to H = ______________

f. F to I = ______________

g. D to H = ______________

h. G to I = ______________

i. D to F = ______________

j. E to H = ______________

TEST

(NOTE: Test questions 10 through 12 list assignment sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

10. Use a rule to measure objects.

11. Circuit a print.

12. Determine wire sizes for blueprint conduit runs.

BLUEPRINT READING
UNIT III

ANSWERS TO TEST

1. a. 3
   b. 7
   c. 5
   d. 1
   e. 4
   f. 2
   g. 6

2. a. Sizes
   b. Types and quality of building materials
   c. Methods of construction
   d. Material symbols
   e. Miscellaneous information
   f. Legend of specific symbols and abbreviations used to identify electrical equipment

3. a. General outlets
      1) Standard outlet
      2) Exit light
      3) Ceiling light
      4) Ceiling lighting outlet for recessed fixture
      5) Lamp holder
      6) Lamp holder with pull switch
      7) Junction box
      8) Drop cord
      9) Fan outlet

ANSWERS TO TEST

b. Convenience outlets

  1) Duplex receptacle
  2) Duplex grounding outlet
  3) Special purpose (description in specifications)
  4) Duplex special purpose
  5) Weatherproof
  6) Range
  7) Switch with single receptacle
  8) Switch with double receptacle
  9) Floor
  10) Radio and double receptacle

c. Switch outlets

  1) Single-pole switch
  2) Double-pole switch
  3) Three-way switch
  4) Four-way switch
  5) Switch and pilot lamp
  6) Weatherproof switch
  7) Fused switch

d. Panels, circuits, auxiliary, and miscellaneous

  1) Thermostat
  2) Lighting panel
  3) Power panel
  4) Controller

ANSWERS TO TEST

5) Isolating switch

6) Exposed branch circuit

7) Branch circuit concealed in floor

8) Branch circuit concealed in ceiling or wall

9) Auxiliary system circuit

10) Push button

11) Buzzer

12) Bell

13) Fire alarm bell

14) Automatic fire alarm device

15) Interconnection box

4. a. Plot plan

b. Elevations

c. Floor plan

d. Details

e. Foundation plan

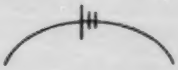
5. a. Minimum standards

b. Type of equipment

c. Type of installation

d. Special instructions

6. a. Run #1 One hot wire

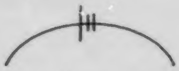


One grounded conductor (neutral)

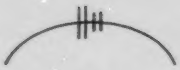
One green equipment grounding wire

ANSWERS TO TEST

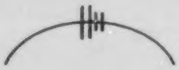
b. Run #2 One hot wire
One neutral wire
One equipment ground wire



c. Run #3 One hot wire
One switched wire
One neutral wire
One green grounding wire



d. Run #4 One hot wire
One switched wire
One neutral wire
One green grounding wire



7. a. 3
   b. 5
   c. 1
   d. 2
   e. 4

8. a. Determine wire size
   b. Determine number of wires in conduit run
   c. Determine conduit size from Tables 3A and 3B in *NEC* Chapter 9

9. a. 4 1/16 inches
   b. 1 1/8 inches
   c. 1 11/16 inches
   d. 3 3/8 inches
   e. 3 5/16 inches
   f. 2 inches
   g. 2 3/16 inches
   h. 1 1/2 inches
   i. 1 1/16 inches
   j. 1 11/16 inches

ANSWERS TO TEST

10. Evaluated to the satisfaction of the instructor

11. Evaluated to the satisfaction of the instructor

12. Evaluated to the satisfaction of the instructor

INTERRUPTING DEVICES
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to install safety switches, test cartridge fuses, wire a load center or breaker panel, and disassemble and reassemble a magnetic motor starter. The student will show this knowledge by completing assignment sheet, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with interrupting devices.
2. Match types of safety switches to their correct applications.
3. Match types of molded-case breakers to their correct industrial uses.
4. Match types of protective devices to their correct uses.
5. Calculate fuse sizes.
6. Demonstrate the ability to
    a. Install a safety switch.
    b. Test cartridge fuses.
    c. Wire a load center or breaker panel.
    d. Disassemble and reassemble a magnetic motor starter.

INTERRUPTING DEVICES
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Order materials planned to supplement unit.

      1. Most recent copy of *Electrical Protection Handbook: Selecting Protective Devices* from Bussmann Manufacturing Division of McGraw-Edison Company.

      2. Catalogs from General Electric and Westinghouse supply companies so that students can become familiar with panel and switchboard information.

         (NOTE: These materials are available from most electrical supply houses.)

      3. Copies of the *National Electrical Code.*

   B. Make transparency.

   C. Gather, or locate in the shop, samples of fuses, breakers, and motor starter disconnects.

   D. Obtain from a local electrical supply house various types of safety switches and molded-case breakers.

   E. Provide students with objective sheet.

   F. Discuss unit and specific objectives.

   G. Provide students with information, assignment, and job sheets.

   H. Discuss information and assignment sheets.

      1. Discuss terms associated with interrupting devices, using Information Sheet, Section I and actual devices or pieces of equipment. Discuss with students the similarities and differences among the devices.

      2. Discuss types of safety switches and their applications, using Information Sheet, Section II and Transparency #1. Show students the different types of safety switches available, including rain-type, heavy duty, single phase, and three phase. Encourage students to equate enclosure style with the switch's particular use.

      3. Discuss types of molded-case breakers in industrial use, using Information Sheet, Section III. Show students actual breakers that you have gathered, or arrange for a field trip to a local electrical supply house so that students may see many types of breakers.

SUGGESTED ACTIVITIES

4. Discuss the types of protection protective devices provide, using Information Sheet, Section IV. Make sure that students realize that protective devices include relays and lightning arresters, as well as fuses and different types of breakers now found in industry.

5. Explain how to calculate fuse sizes. Remind the students that the *National Electrical Code* is very specific on the selection of fuse sizes for a particular load. While information in the *NEC* is sometimes obscure and is quite spread out, most manufacturers of fuses will provide a chart such as that in Assignment Sheet #1. Have students complete Assignment Sheet #1. It might be a good extracurricular activity to have the students match the chart in Assignment Sheet #1 to the particular areas in the *NEC*. This exercise will also assist students in learning the layout of the *NEC*.

6. Demonstrate in the shop the proper process for installing safety switches (Job Sheet #1) and for testing cartridge fuses (Job Sheet #2). Job Sheets #1 and #2 should be done in sequence because it is necessary to first install and power a safety switch before testing fuses. Have students complete Job Sheets #1 and #2.

7. Demonstrate in the shop the wiring of a load center or breaker panel (Job Sheet #3). Remind students that neatness is important: the neater the panel, the easier it will be later on to troubleshoot or to add new circuits. Have students complete Job Sheet #3.

8. Demonstrate in the shop the disassembly and reassembly of a magnetic motor starter (Job Sheet #4). Remind students that the magnetic motor starter is not only used to start and stop the motor, but to provide interruption for the motor circuit through its overload protection. Have students complete Job Sheet #4.

I. Give test.

J. Reteach if necessary.

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency #1 — Ground Fault Relaying

E. Assignment Sheet #1 — Calculate Fuse Sizes

SUGGESTED ACTIVITIES

F. Job Sheets

1. Job Sheet #1 — Install a Safety Switch
2. Job Sheet #2 — Test Cartridge Fuses
3. Job Sheet #3 — Wire a Load Center or Breaker Panel
4. Job Sheet #4 — Disassemble and Reassemble a Magnetic Motor Starter

G. Test

H. Answers to test

III. Unit references

A. "Buy Log: Low Voltage Equipment," GEP-1100C. New York: General Electric, 1979.

B. *Electrical Protection Handbook: Selecting Protective Devices,* Bulletin SPD-78, 5th ed. St. Louis, Missouri: Bussmann Manufacturing Division of McGraw-Edison Company, 1978.

INTERRUPTING DEVICES
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Air circuit breaker — Breaker in which all parts operate in air

B. Amperage rating — Maximum current-carrying capacity of a device

C. Arc chute — Cover around contacts that protects surrounding parts from arcing

D. Bus — Set of two or more electric conductors that serve as common connections between load circuits (in DC systems) or phases (in AC systems) of the source of electric power

E. Class R switches — Switches that require Class R fuses with a 200,000-ampere interrupting rating

(NOTE: The fuse clips in Class R switches will not accept Class H or renewable-link fuses.)

F. Current-limiting overcurrent protective device — Device that, when interrupting current in its current-limiting range, reduces the short-circuit current flowing in the faulted circuit to substantially less than would otherwise flow into the fault

G. Dual-element fuse — Fuse that has within it a thermal cutout element with a time delay that permits momentary harmless inrush currents to flow without harming the fuse

(NOTE: Dual-element fuses should not be confused with fuses with two renewable links in a fuse cartridge.)

H. Fault current — Current that flows from one conductor to ground or another conductor because of an abnormal connection or arc between the two

I. Ground fault — Accidental connection between an electrical circuit or equipment and the earth or some conducting body that serves in place of the earth

J. Ground-fault circuit interrupter — Breaker designed to protect individuals and equipment by deenergizing or tripping a circuit when current to ground reaches 0.005 amperes

K. Interrupting rating — Maximum available short-circuit current that an overcurrent device can safely interrupt without damage to itself

INFORMATION SHEET

L. Oil circuit breaker — Load interrupter in which the interrupting contacts operate submerged in transformer oil

M. Overload — Larger than normal current flowing within the normal current path

N. Panelboard — Enclosure consisting of one or more panel units; designed to be placed in a cabinet or cutout box against a wall and to be accessible only from the front

(NOTE: There are generally two types of panelboards: 1) assembly of switches or breakers in an enclosure to feed various heavy loads, and 2) enclosure generally with a main breaker panel to supply small branch circuits.)

O. Selective coordination — The use of interrupting devices sized and installed so that the one nearest the fault or overloaded machine will open before any of the larger upstream devices open

(NOTE: Selective coordination effectively reduces the outage to a smaller plant area or number of machines.)

P. Short circuit — Larger than normal current flowing outside the normal current path

Q. Single-element fuse — Fuse that contains only one element and is not designed to carry an overload

(NOTE: Single-element fuses blow quickly.)

R. Time-current curve — Plotted curve showing how long a fuse or breaker will carry an overload before opening the circuit

(NOTE: The time period varies for each type of fuse.)

S. Voltage rating — Maximum voltage at which a device is designed to operate

II. Applications of types of safety switches (Job Sheet #1)

A. Standard — Residential and light commercial use

B. Heavy-duty — Industrial and other rugged use

C. Indoor — Indoor use

D. Raintight — Outdoor use

E. Fusible — Overload and short-circuit protection

INFORMATION SHEET

F. Nonfusible — Disconnect only

G. Two-pole — Single-phase loads

H. Three-pole — Three-phase loads

III. Industrial uses of molded-case breakers (Job Sheet #3)

A. Standard — Conventional overload and short-circuit protection

B. High-break — Conventional overload and short-circuit protection; has high interrupting capacity (IC) rating

C. Magnetic only — Short-circuit protection only; no overload protection

D. View-break — Conventional overload and short-circuit protection; has clear window to view contacts

E. Molded-case switch — Disconnect only; offers no thermal or magnetic protection

(NOTE: A molded-case switch is also called a *nonautomatic circuit interrupter.*)

IV. Protective devices and their uses (Transparency #1; Assignment Sheet #1; Job Sheets #2 and #4)

(CAUTION: When testing or replacing protective devices, follow the manufacturer's instructions. A skilled technician never throws away the instruction sheet or booklet that comes with a new relay or other protective device because some solid-state relays or protective devices can be destroyed by the voltage placed on them by an ohmmeter.)

A. Lightning arrester — Protects electrical systems and equipment from damage due to lightning or transient surges

B. Overcurrent device — Triggers operation of breakers or contactors to interrupt excessive currents

EXAMPLES: Magnetic, thermal, or solid-state sensing devices

C. Fuse — Melts an enclosed metal link and extinguishes the resulting arc in case of overload or short circuit

D. Relay — Switches signals on or off by means of a solenoid and contacts, or through solid-state components

(NOTE: Relays may be solid-state with no moving parts or they may be magnetic.)

INFORMATION SHEET

E. Ground-fault circuit interrupter — Senses any imbalance of current going to and returning from a load, and trips breaker when as little as 0.005 ampere flows outside normal circuit path

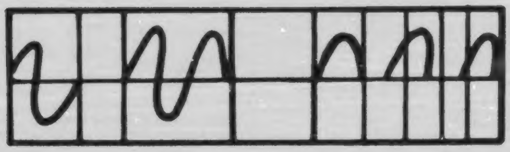
F. Arcing ground-fault relay — Protects panelboard or switchboard internal bus work by opening main breaker

(NOTE: Ground faults on switch gear buses and bus ducts may be interpreted as heavy loads by normal overcurrent relays and so will not initiate a trip signal soon enough to prevent destruction of thousands of dollars of equipment.)

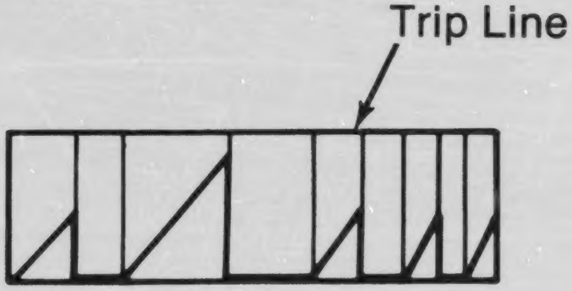
G. Shunt-trip breaker — Turns breaker off from a remote controller

(NOTE: The shunt-trip breaker contains a solenoid trip device.)

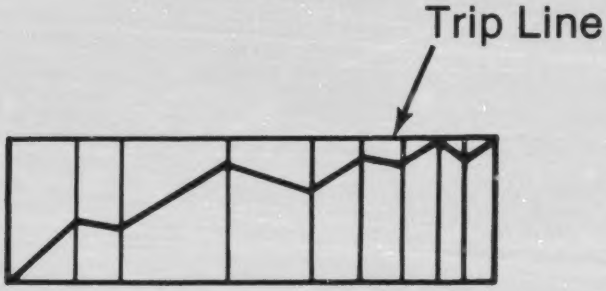
Ground Fault Relaying



Intermittent Ground Fault



Ground Fault Relay Without Memory - Resets After Each Arc



Ground Fault Relay with Memory Circuit - Does Not Reset So Quickly and Trips to Save Expensive Power Equipment

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INTERRUPTING DEVICES
UNIT I

ASSIGNMENT SHEET #1 — CALCULATE FUSE SIZES

NAME ______________________________ SCORE ______________

The electrical maintenance technician should be able to calculate appropriate fuse sizes by referring to reference materials and charts and by calculating percentages correctly.

Use the guidelines for sizing dual-element time-delay fuses and the line diagram that follows to calculate fuse amperages in the problems that follow. Show your work.

Refer to *NEC* Article 240-6 for standard ampere ratings for fuses.

Dual-Element Time-Delay Fuse

1 **Main Service**. Size fuse according to method in **4**.

2 **Feeder Circuit With No Motor Loads**. The fuse size must be at least 125 percent of the continuous load plus 100 percent of the noncontinuous load. Do not size the fuse larger than the ampacity of the conductor.

3 **Feeder Circuit With All Motor Loads**. Size the fuse at 150 percent of the full-load current of the largest motor plus full-load current of all other motors.

4 **Feeder Circuit With Mixed Loads**. Size fuse at sum of:

a. 150 percent of the full-load current of the largest motor.
b. 100 percent of the full-load current of all other motors.
c. 125 percent of the continuous nonmotor load.
d. 100 percent of the noncontinuous nonmotor load.

5 **Branch Circuit With No Motor Load**. The fuse size must be at least 125 percent of the continuous load plus 100 percent of the noncontinuous load. Do not size the fuse larger than the ampacity of the conductor.

6 **Motor Branch Circuit With Overload Relays**. Where overload relays are sized for motor running overload protection, the following fuses provide back-up protection and short-circuit protection:

a. Motor 1.15 service factor or 40°C rise: size fuse at 125 percent of motor full-load current or next higher standard size.

b. Motor less than 1.15 service factor or 40°C rise: size the fuse at 115 percent of the motor full-load current or the next higher standard fuse size.

ASSIGNMENT SHEET #1

7 **Motor Branch Circuit With Fuse Protection Only.** Where the fuse is the only motor protection, the following fuses provide motor running overload protection and short-circuit protection:

a. **Motor 1.15 service factor or 40°C rise:** size the fuse at 110 percent to 125 percent of the motor full-load current.

b. **Motor less than 1.15 service factor or over 40°C rise:** size fuse at 100 percent to 115 percent of motor full-load current.

8 **Large Motor Branch Circuit.** Fuse larger than 600 amps. For large motors, size KRP-C HI-CAP time-delay fuse at 150 percent to 225 percent of the motor full-load current, depending on the starting method such as part-winding starting or reduced-voltage starting.

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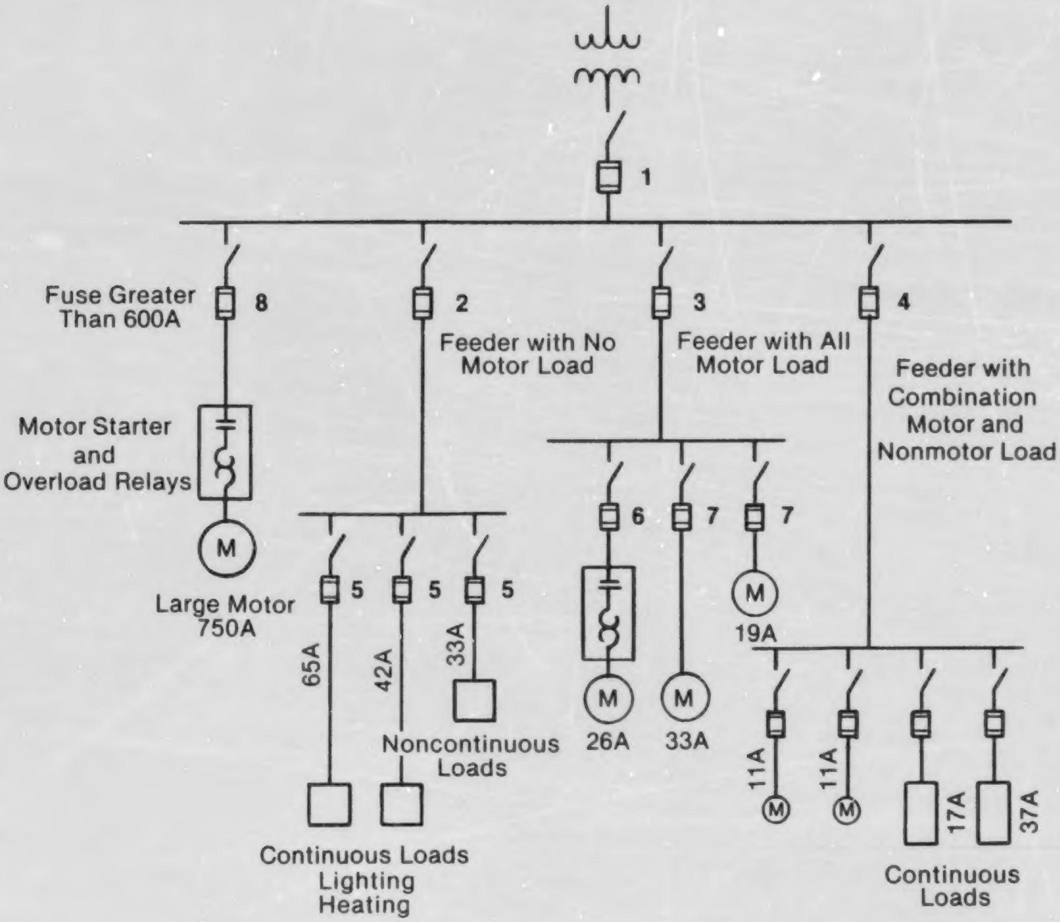
ASSIGNMENT SHEET #1


1
Fuse Greater Than 600A
8
Motor Starter and Overload Relays
M
Large Motor 750A
2
Feeder with No Motor Load
5
5
5
65A
42A
33A
Noncontinuous Loads
Continuous Loads Lighting Heating
3
Feeder with All Motor Load
6
7
7
M
M
M
26A
33A
19A
4
Feeder with Combination Motor and Nonmotor Load
11A
11A
M
M
17A
37A
Continuous Loads

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ASSIGNMENT SHEET #1

A. What fuse range may be used with the large motor branch circuit?

Fuse = ______________________ to ______________________ amps

B. What fuse size is required for the 65-ampere continuous load?

Fuse = ______________________ amps

C. What fuse size is required for the feeder circuit with no motor loads?

Fuse = ______________________ amps

D. What fuse size is required for the feeder circuit with all motor loads?

Fuse = ______________________ amps

ASSIGNMENT SHEET #1

E. If the service factor is 1.15, what fuse size is required for the motor branch circuit with overload relay?

Fuse = ______________________ amps

F. If the service factor is 1.15, what fuse range may be used for the branch circuit with the 33-ampere load?

Fuse = ______________________ amps

G. What fuse size is required for the feeder circuit with combination motor and nonmotor loads?

Fuse = ______________________ amps

H. What size main service fuse is required?

Fuse = ______________________ amps

INTERRUPTING DEVICES
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 1,200 to 2,000

B. 90

C. 175

D. 100

E. 35

F. 40 to 45

G. 100

H. 1,600

INTERRUPTING DEVICES
UNIT I

JOB SHEET #1 — INSTALL A SAFETY SWITCH

I. Equipment and materials

- A. General-duty safety switch (indoor or raintight, three-pole, four-wire, two-fuse switch, 250-volt, 60-ampere rating)
- B. Pouch tools
- C. Piece of #6 insulated wire, 10 feet long
- D. 6 #10 sheet metal screws, 3/4 inch long
- E. Backboard and mounting screws
- F. 3 FRNR fuses, 60 amperes
- G. Level
- H. 2 EMT conduit connectors, 1-inch diameter

II. Procedure

- A. Determine exact installation location
- B. Install a mounting screw for the top mounting hole
- C. Hang switch box on the screw

  (NOTE: The hole in the upper middle back of housing should slip over the screw head.)
- D. Level the box
- E. Locate holes for the remaining two mounting screws
- F. Install the lower two mounting screws

  (NOTE: Be sure that box is level.)
- G. Open 1-inch knockout holes in top and bottom of switch housing
- H. Install a 1-inch EMT connector in each knockout hole
- I. Cut six 12-inch lengths of #6 wire
- J. Strip back one end of each piece of wire about 5/8 inch

JOB SHEET #1

K. Install three #6 wires through the 1-inch connector in the top of the switch housing, and connect to line terminals L1, L2, and L3

(NOTE: Install the wires neatly, being careful not to allow the wires to rub against any metal edge.)

L. Firmly tighten terminals L1, L2, and L3

(CAUTION: Loose connections are a chief cause of electrical problems.)

M. Install three pieces of #6 wire through the 1-inch connector in the bottom of the switch housing, and connect to load terminals T1, T2, and T3

(NOTE: Install wires neatly, being careful not to allow the wires to rub against any metal edge.)

N. Firmly tighten terminals T1, T2, and T3

O. Determine length of ground wire by measuring from top of box to ground terminal

P. Cut a piece of #6 wire to the measured length

Q. Strip back the lower end of the ground wire; install in the ground terminal and tighten

R. Install ground wire through bottom hole in switch housing

S. Form the ground wire neatly so that it will not touch any moving part of the switch

T. Strip back upper end of ground wire; install ground wire in switch terminal and tighten

U. Insert the three 60-amp fuses into the fuse clips

(NOTE: Fuse clips must fit tightly on each fuse. Have instructor evaluate your work. If installation is satisfactory, it may be used for completing Job Sheet #2.)

INTERRUPTING DEVICES
UNIT I

JOB SHEET #2 — TEST CARTRIDGE FUSES

I. Equipment and materials

- A. Eye protection
- B. Safety switch assembly from Job Sheet #1
- C. Several fuses, both good and bad
- D. Voltmeter
- E. Live disconnect

II. Procedure

(CAUTION: Live voltages are present during this test. Proper safety precautions should be observed.)

- A. Put on eye protection
- B. Deenergize disconnect
- C. Install fuses
- D. Energize disconnect and leave disc door open
- E. Set voltmeter to appropriate voltage scale
- F. Test voltage on line side of disconnect

  (NOTE: On a 208-volt, three-phase disconnect, 208 volts should be present from L1 to L2, L1 to L3, and L2 to L3.)

- G. Place voltmeter probe #1 on L1 terminal and probe #2 on T2 terminal; voltage should be 208 volts
- H. Move probe #2 to T3 terminal; voltage should be 208 volts
- I. Move probe #1 to L2 terminal and probe #2 to T1 terminal; voltage should be 208 volts
- J. Move probe #2 to T3 terminal; voltage should be 208 volts
- K. Move probe #1 to L3 terminal and probe #2 to T1 terminal; voltage should be 208 volts

JOB SHEET #2

L. Move probe #2 to T2 terminal; voltage should be 208 volts

(NOTE: A lower voltage or no voltage indicates a bad fuse. When meter shows low or no voltage, probe #2 will always be under the fuse that is bad.)

M. Repeat steps B through L using different fuses

(NOTE: Have instructor evaluate work.)

N. Clean work area; clean and put away tools and equipment

INTERRUPTING DEVICES
UNIT I

JOB SHEET #3 — WIRE A LOAD CENTER OR BREAKER PANEL

I. Equipment and materials

- A. Three-phase load center, 200 amperes

  (Cutler-Hammer #CH30JTM200 cover #S-CH7J or equivalent)
- B. 2 three-pole breakers, 30 amperes
- C. 2 three-pole breakers, 30 amperes
- D. 8 single-pole breakers, 20 amperes
- E. Studs or backboard for mounting panel
- F. 4 #10 sheet-metal mounting screws, 3/4 inch long
- G. 3 pieces of #3/0 insulated copper wire, 30 inches each
- H. Piece of #3/0 insulated copper wire, 60 inches long
- I. 10 pieces of #10 insulated wire, 5 feet each (color other than green or white)
- J. 8 pieces of #12 insulated wire, 6 feet each (color other than green or white)
- K. 8 pieces of green #12 insulated wire, 6 feet each
- L. 8 pieces of white #12 insulated wire, 6 feet each
- M. 4 pieces of green #10 insulated wire, 6 feet each

  (NOTE: Length of ground wire may vary depending on location of neutral ground bar. Use good judgment in cutting wire lengths.)
- N. Pouch tools
- O. Allen wrench set
- P. Compression-type EMT connector, 2-inch diameter
- Q. 12 compression-type EMT connectors, 1/2-inch diameter
- R. Compression-type EMT connector, 3/4-inch diameter
- S. Breaker index sheet
- T. Piece of #4 bare wire 3 feet long for use as a grounding electrode conductor

JOB SHEET #3

II. Procedure

A. Before mounting panel, open twelve 1/2-inch knockout holes, one 3/4-inch knockout hole, and one 2-inch knockout hole for EMT conduit

(NOTE: The 2-inch knockout hole will generally be located in the center of the top of the panel. The 1/2-inch and 3/4-inch knockouts may be located in the top or bottom, or both top and bottom.)

B. Install the 1/2-inch and 3/4-inch EMT connectors; tighten snugly

C. Install the 2-inch EMT connector; tighten snugly

D. Mount panelboard in designated location

E. Connect one end of the #4 bare ground wire to the ground bar, allowing other end to hang from bottom of panel

(NOTE: Under actual installation, the lower end of the ground wire would terminate at the grounding electrode.)

F. Strip back one end of each piece of insulated wire approximately 5/8 to 3/4 inch

G. Install one piece of #3/0 wire through the 2-inch connector to the neutral bar connector; arrange the wire neatly to lay in back corner of the panel; then insert wire in neutral bar terminal and tighten snugly

(NOTE: The neutral conductor should lay in the back corner of the panel to leave adequate room for the other wires and breakers.)

H. Install the remaining #3/0 wires through the 2-inch connector, and insert wires in the main breaker connectors

(NOTE: Arrange wires neatly, allowing room for the branch-circuit conductors.)

I. Plug the three-pole breakers into the panel bus, one breaker on the right, the other on the left at the top positions

J. Plug the two two-pole breakers into the panel bus, one breaker on the left, the other on the right in the top positions

K. Plug the eight single-pole breakers into the panel bus, four breakers on the left, and four on the right in the remaining positions

JOB SHEET #3

L. Install remaining wires

1. For the three-pole breakers, insert three #10 colored wires (other than green or white) and one #10 green wire through the 3/4-inch connector

   (NOTE: Extend all wires into the panel far enough to reach the neutral or ground bar, especially the green wire after arranging it in the back corner of panel down to ground bar.)

2. For the two-pole breakers, insert two #10 colored and one #10 green wire for each breaker

3. For the single-pole breakers, insert one #12 colored, one #12 white for neutral, and one #12 green wire for each breaker

M. Tag or mark by number each group of wires that goes to a specific breaker

N. Fold back out of the way all branch circuit wires inside the panel to provide clear working space inside panel

O. Trim out panelboard

1. Work the green wires one at a time, arranging them against back of panel in corners and making right angle bends to the ground bar terminals

2. Cut, strip, and insert wires into terminals; tighten snugly

   (NOTE: This method places this group of wires in the back of the panel, out of the way of neutral and circuit wires; also, it gives the technician an organized procedure for doing the work neatly.)

3. Work the white neutral wires one at a time, laying the wires near the green wires in the back spaces and corners of the panel and making bends to the neutral or ground bar

4. Cut, strip, and insert wires into terminals; tighten snugly

5. Work the colored circuit wires

   a. Work the #10 wires one at a time to the left three-pole breaker, forming the wire to lay neatly toward the back and side of panel; make right-angle bends to bring wire horizontally toward proper breaker terminal; make additional right-angle bends to bring wires outward and then into breaker

      (NOTE: This procedure makes it easy to trace wires, provides enough wire length to pull out and check loads with a clamp-on ammeter, and produces a neat, professional-looking job.)

b. Work the #10 wires to the right three-pole breaker, using the procedure outlined in step a

c. Work the wires to the two-pole breakers, using the procedure outlined in step a

d. Work the single-pole circuit wires, making neat bends and using the same procedure outlined in step a

6. Double-check to make sure that all connections make good contact and are tight

(NOTE: Have instructor evaluate your work.)

P. Carefully dismantle the assembly and store parts in proper places

Q. Clean work area; clean and put away all tools and equipment

INTERRUPTING DEVICES
UNIT I

JOB SHEET #4 — DISASSEMBLE, INSPECT, AND REASSEMBLE A MAGNETIC MOTOR STARTER

I. Equipment and material

A. Three-phase magnetic starter

B. Pouch tools

II. Procedure

(NOTE: It is best to have a starter on a bench for this procedure.)

A. Loosen screws on cover plate of coil assembly

B. Lift cover straight off coil assembly

C. Lift coil assembly straight out of starter

D. Disassemble magnetic assembly

E. Check armature for loose laminations

F. Check shading coils for cracks

G. Check magnetic coil for cracks

H. Loosen contact assembly screws

I. Lift contact assembly straight out of starter

J. Check points for pitting and carbon deposits

K. Check spring tension on contacts

L. Check contacts in starter base for pitting and carbon deposits

M. Reverse procedure to reassemble starter

(NOTE: Have instructor check the reassembled starter.)

N. Put away equipment and materials

INTERRUPTING DEVICES
UNIT I

TEST

NAME ____________________________________ SCORE ______________

1. Match to their correct definitions terms associated with interrupting devices. Write the correct numbers in the blanks. Terms and definitions are continued on the next page.

______a. Maximum voltage at which a device is designed to operate

______b. Larger than normal current flowing within the normal current path

______c. Plotted curve showing how long a fuse or breaker will carry an overload before opening the circuit

______d. Larger than normal current flowing outside the normal current path

______e. Fuse that has within it a thermal cutout element with a time delay that permits momentary harmless inrush currents to flow without harming the fuse

______f. The use of interrupting devices sized and installed so that the one nearest the fault or overloaded machine will open before any of the larger upstream devices open

______g. Cover around contacts that protects surrounding parts from arcing

______h. Breaker in which all parts operate in air

______i. Enclosure consisting of one or more panel units; designed to be placed in a cabinet or cutout box against a wall and to be accessible only from the front

______j. Maximum current-carrying capacity of a device

______k. Fuse that contains only one element and is not designed to carry an overload

______l. Accidental connection between an electrical circuit or equipment and the earth or some conducting body that serves in place of the earth

1. Overload
2. Short circuit
3. Time-current curve
4. Amperage rating
5. Air circuit breaker
6. Selective coordination
7. Dual-element fuse
8. Arc chute
9. Voltage rating
10. Single-element fuse
11. Panelboard
12. Ground fault

TEST

_____m. Maximum available short-circuit current that an overcurrent device can safely interrupt without damage to itself

_____n. Switches that require Class R fuses with a 200,000-ampere interrupting rating

_____o. Current that flows from one conductor to ground or another conductor because of an abnormal connection or arc between the two

_____p. Breaker designed to protect individuals and equipment by deenergizing or tripping a circuit when current to ground reaches 0.005 amperes

_____q. Device that, when interrupting current in its current-limiting range, reduces the short-circuit current flowing in the faulted circuit to substantially less than would otherwise flow into the fault

_____r. Load interrupter in which the interrupting contacts operate submerged in transformer oil

_____s. Set of two or more electric conductors that serve as common connections between load circuits (in DC systems) or phases (in AC systems) of the source of electric power

13. Ground-fault circuit interrupter
14. Fault current
15. Current-limiting overcurrent protective device
16. Interrupting rating
17. Oil circuit breaker
18. Class R switches
19. Bus

2. Match types of safety switches to their correct applications. Write the correct numbers in the blanks. Applications are continued on the following page.

_____a. Residential and light commercial use

_____b. Three-phase loads

_____c. Outdoor use

_____d. Industrial and other rugged use

_____e. Overload and short-circuit protection

_____f. Single-phase loads

1. Fusible
2. Two-pole
3. Standard
4. Indoor
5. Nonfusible
6. Three-pole
7. Heavy-duty
8. Raintight

TEST

_____g. Indoor use

_____h. Disconnect only

3. Match types of molded-case breakers to their correct industrial uses. Write the correct numbers in the blanks.

_____a. Conventional overload and short-circuit protection

_____b. Disconnect only; offers no thermal or magnetic protection

_____c. Short-circuit protection only; no overload protection

_____d. Conventional overload and short-circuit protection; has a clear window to view contacts

_____e. Conventional overload and short-circuit protection; has high interrupting capacity (IC) rating

1. Magnetic only
2. High-break
3. View-break
4. Standard
5. Molded-case switch

4. Match types of protective devices to their correct uses. Write the correct numbers in the blanks.

_____a. Turns breaker off from a remote controller

_____b. Protects electrical systems and equipment from damage due to lightning or transient surges

_____c. Protects panelboard or switchboard internal bus work by opening main breaker

_____d. Triggers operation of breakers or contactors to interrupt excessive currents

_____e. Melts an enclosed metal link and extinguishes the resulting arc in case of overload or short-circuit

_____f. Switches signals on or off by means of a solenoid and contacts, or through solid-state components

_____g. Senses any imbalance of current going to and returning from a load, and trips breaker when as little as 0.005 ampere flows outside normal circuit path

1. Fuse
2. Arcing ground-fault relay
3. Relay
4. Shunt-trip breaker
5. Overcurrent device
6. Lightning arrester
7. Ground-fault circuit interrupter

TEST

(NOTE: Test questions 5 and 6 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

5. Calculate fuse sizes.
6. Demonstrate the ability to
   - a. Install a safety switch.
   - b. Test cartridge fuses.
   - c. Wire a load center or breaker panel.
   - d. Disassemble and reassemble a magnetic motor starter.

INTERRUPTING DEVICES
UNIT I

ANSWERS TO TEST

1.	a.	9	f.	6	k.	10	p.	13
	b.	1	g.	8	l.	12	q.	15
	c.	3	h.	5	m.	16	r.	17
	d.	2	i.	11	n.	18	s.	19
	e.	7	j.	4	o.	14		

2.	a.	3	e.	1
	b.	6	f.	2
	c.	8	g.	4
	d.	7	h.	5

3.	a.	4	d.	3
	b.	5	e.	2
	c.	1		

4.	a.	4	e.	1
	b.	6	f.	3
	c.	2	g.	7
	d.	5		

5. Evaluated to the satisfaction of the instructor

6. Performance skills evaluated to the satisfaction of the instructor

CONDUCTORS
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to select and install proper conductors in a raceway. The student will show this knowledge by completing assignment sheets, job sheet, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with conductors to their correct definitions.
2. List factors that determine type and size of conductors.
3. Select from a list characteristics of good connections.
4. Label types of connectors, terminals, and lugs.
5. Identify types of insulation, given their correct code letters, applications, and characteristics.
6. Select conductors for various ampacities and temperatures.
7. Calculate ampacity of conductors, given number of conductors in raceway.
8. Calculate ampacity and conductor sizes for specific types of loads.
9. Use tables to calculate voltage drops of selected circuits.
10. Select proper types of insulation.
11. Demonstrate the ability to use a fish tape to install wire in conduit.

CONDUCTORS
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

A. Obtain for class manufacturers' conductor catalogs.

EXAMPLE: *Greenlee: Timesaving Tools for Electricians, Maintenance Men and Industry* by Ex-cello Corp.

B. Obtain one copy of the current *National Electrical Code* for each member of the class.

(NOTE: Assignment sheets and answers in this unit are based on the 1981 *National Electrical Code.*)

C. Arrange for a field trip to an industry site so that students may note conduit runs, panel equipment, junction boxes, vaults, manholes, and allowances that have to be considered in purchasing heavy conductors.

D. Provide students with objective sheet.

E. Discuss unit and specific objectives.

F. Provide students with information, assignment, and job sheets.

G. Discuss information sheet.

1. Discuss terms and definitions, using Information Sheet, Section I. Show students samples of wire with different types of insulation, as well as fish tapes, wire-pulling compound, pull ropes, and cable benders.

2. Discuss factors that determine type and size of conductors, using Information Sheet, Section II and Assignment Sheets #1 through #4. Be sure that the student understands that there are many variables for determining the size of the conductor. These variables include not only the type of load to be served, but also the length of the run, the number of conductors in the raceway, and the ambient temperature where the conductors are going to be run.

3. Discuss characteristics of good connections, using Information Sheet, Section III. Remind the students that a good connection reduces the possibility of heat and arcing. Heat and arcing may not only damage the wire, but also may injure the electrical technician.

SUGGESTED ACTIVITIES

4. Discuss types of connectors, terminals, and lugs, using Information Sheet, Section IV. Show samples to the students. Discuss proper mounting, tool selection, and installation of specific connectors, terminals, and lugs.

5. Discuss types of insulation, using Information Sheet, Section V and Assignment Sheet #5. Remind students that each type of insulation is designed for a specific duty under certain conditions, and that these conditions are specified in the *National Electrical Code*.

H. Demonstrate and discuss procedures outlined in job sheet.

I. Give test.

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Assignment sheets

1. Assignment Sheet #1 — Select Conductors for Various Ampacities and Temperatures

2. Assignment Sheet #2 — Calculate Ampacity of Conductors, Given Number of Conductors in Raceway

3. Assignment Sheet #3 — Calculate Ampacity and Conductor Size for Specific Types of Loads

4. Assignment Sheet #4 — Use Tables to Calculate Voltage Drops of Selected Circuits

5. Assignment Sheet #5 — Select Proper Types of Insulation

E. Answers to assignment sheets

F. Job Sheet #1 — Use a Fish Tape to Install Wire in Conduit

G. Test

H. Answers to test

SUGGESTED ACTIVITIES

III. Unit references

A. *Greenlee: Timesaving Tools for Electricians, Maintenance Men and Industry*. Catalog. Rockford, Illinois: Greenlee Tool Division, 1982.

B. *National Electrical Code*. Boston, Massachusetts: National Fire Protection Association, 1981.

C. Taylor, Mark. *Residential Wiring*. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1978.

CONDUCTORS
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Ampacity — Current-carrying capacity of conductors; expressed in amperes

B. Insulated — Conductor encased within material of composition and thickness recognized by the *National Electrical Code* as electrical insulation

C. Covered — Conductor encased within material of composition and thickness not recognized by the *National Electrical Code* as electrical insulation

D. Copper wire — Conductor made of copper

E. Aluminum wire — Conductor made of aluminum

F. Copper-clad aluminum — Aluminum conductor with an outer coating of copper metallurgically bonded to the aluminum core

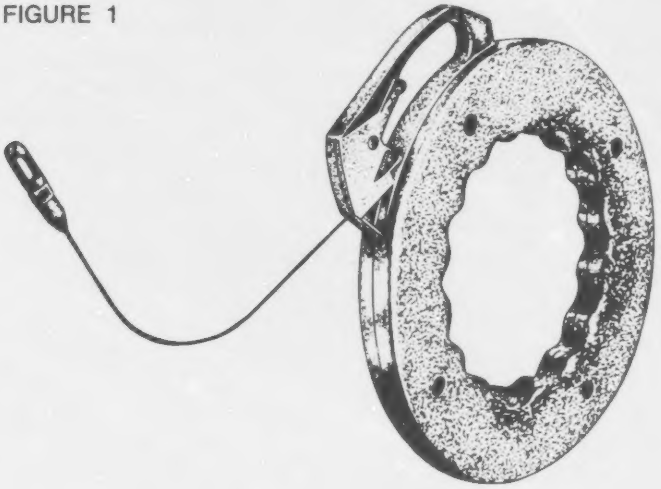
G. Color coding — Assigning colors to conductors based on their uses

EXAMPLES: Neutral conductor (white), equipment ground wire (green)

H. Fish tape — Long tape of steel, nylon, or other material used to push or pull a conductor into a raceway (Figure 1)

EXAMPLE:

FIGURE 1



INFORMATION SHEET

- I. Wire-pulling compound — Compound of soap and other substances used to lubricate conductors being pulled or pushed into a raceway
- J. Winch — Manual or motor-powered mechanical device used to pull conductors into a raceway
- K. Wire dispenser — Movable rack used to hold one or more reels of wire so that wire can be easily pulled off reel and fed into raceway
- L. Pull rope — Strong rope of nylon or other substance used to pull heavy conductors into raceways
- M. Power fish-tape system — Vacuum or air pressure system for installing a pull cord in a raceway in order to pull in the heavy pull rope for heavy and long pulls
- N. Cable benders — Mechanical or hydraulic devices used to bend heavy conductors in panels and junction boxes
- O. Voltage drop — Voltage lost in forcing load amperes through conductors

II. Factors that determine type and size of conductors (Assignment Sheets #1-#4)

(NOTE: *NEC* Table 310-16 covers sizing for most general wiring for 60°C to 90°C temperature ranges.)

A. Full-load amperes

B. Number of conductors in raceway

(NOTE: See *NEC*, Table 310-16, Note 8.)

C. Type load to be served

EXAMPLES: Fixed electric space-heating requires conductors for not less than 125 percent of full load: *NEC* 424-3(a) and (b).

Single motor requires conductors for 125 percent of full-load ampacity: *NEC* 430-22.

Two or more motors require conductors for 125 percent of largest motor, plus sum of full-load ampacity of all smaller motors: *NEC* 430-24.

All continuous motor loads require conductors of at least 115 percent to 125 percent ampacity: *NEC* 430-32.

D. Length of run

(NOTE: See *NEC*, Table 310-16, Note 12, and *NEC* Articles 210-19 and 215-2.)

INFORMATION SHEET

E. Ambient temperature encountered

(NOTE: See *NEC*, Tables 310-16 and 310-18.)

EXAMPLES: Rooftop temperatures in summer approach the water boiling point of 100°C.

Boiler and furnace rooms may reach temperatures near 100°C.

F. Voltage

(NOTE: Most conductors for general use are rated for 600 volts. Higher voltage ratings are generally specified on a special order.)

EXAMPLE: 13,000-volt service entrance conductors

III. Characteristics of good connections

A. Are clean

B. Are tight

C. Are strong

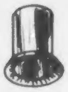
D. Provide full contact

E. Do not place copper and aluminum in direct contact

IV. Types of connectors, terminals, and lugs (Figures 2-12)

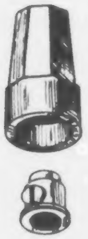
A. Crimp sleeve connector

FIGURE 2



B. Setscrew lug

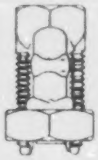
FiGURE 3



INFORMATION SHEET

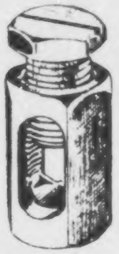
C. Split-bolt lug

FIGURE 4



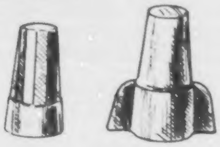
D. Service-entrance lug

FIGURE 5



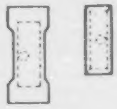
E. Wire-nut lugs

FIGURE 6



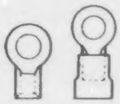
F. Crimp-type butt connectors

FIGURE 7



G. Ring lugs

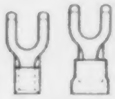
FIGURE 8



INFORMATION SHEET

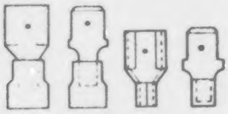
H. Spade connectors

FIGURE 9



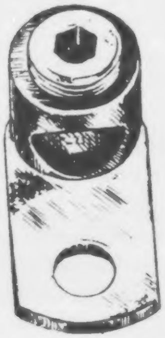
I. Quick-disconnect connectors

FIGURE 10



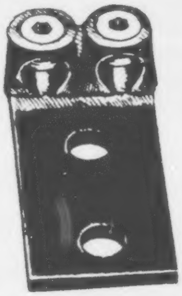
J. Single terminal

FIGURE 11



K. Twin terminal

FIGURE 12



INFORMATION SHEET

V. Types of insulation (Table 1)

TABLE 1

Insulation Name	Code Letters	Application	Characteristics
Thermoplastic	T	Dry locations	Flame retardant
Moisture-resistant thermoplastic	TW	Dry and wet locations	Flame retardant, moisture resistant
Heat-resistant thermoplastic	THHN	Dry locations	Flame retardant, heat resistant
Moisture-, heat-, and oil-resistant thermoplastic	MTW	Machine tool wiring in wet locations as permitted in NFPA Standard No. 79 (See Article 670) Machine tool wiring in dry locations as permitted in NFPA Standard No. 79 (See Article 670)	Flame retardant, moisture, heat, and oil resistant
Moisture- and heat-resistant thermoplastic	THW	Dry and wet locations Special applications within electric discharge lighting equipment; limited to 1,000 open-circuit volts or less (size 14-8 only as permitted in Section 410-31)	Flame retardant, moisture and heat resistant
Moisture- and heat-resistant thermoplastic	THWN	Dry and wet locations	Flame retardant, moisture and heat resistant

CONDUCTORS
UNIT II

ASSIGNMENT SHEET #1 — SELECT CONDUCTORS FOR VARIOUS AMPACITIES AND TEMPERATURES

NAME ______________________________ SCORE ____________

The electrical technician must be able to select proper conductors for various ampacities and temperatures. This skill requires that the technician be able to locate and read *National Electrical Code* tables.

Select conductors for various ampacities and temperatures. Use the *National Electrical Code,* Table 310-16 for not more than three conductors in a raceway. Use the temperature rating column that is the same or the next higher rating than the required temperature, then select the size conductor for the required or next higher ampacity. Refer only to the sizes given for copper wiring.

EXAMPLES: What wire size is required for a load of 55 amperes at 70°C? The answer is #6 AWG. This is obtained by referring to the 75°C column because the required temperature is above 60°C but less than 75°C. Because there is no value given for 55 amperes, you must use the gauge of wire approved for the next higher rating, which is 65 amperes in this case.

What wire size is required for a load of 25 amperes at 68°C? The answer is #10 AWG. Although the chart under the 75°C column shows that #12 AWG is acceptable for 25 amperes at this temperature, the obelisk(†) indicates a note below the table. According to the note, the overcurrent protection for each type of conductor shown shall not exceed 20 amperes for #12 AWG wire. Thus, you will need to use the next heavier gauge, #10 AWG, which provides overcurrent protection up to 30 amperes.

ASSIGNMENT SHEET #1

Amperes	**Temperature**	**Wire Size Per *NEC* 310-16**
20	65°C	A. ____________________
35	75°C	B. ____________________
37	85°C	C. ____________________
110	87°C	D. ____________________
110	65°C	E. ____________________
232	75°C	F. ____________________
400	85°C	G. ____________________
540	60°C	H. ____________________
67	65°C	I. ____________________
83	75°C	J. ____________________
190	70°C	K. ____________________

CONDUCTORS
UNIT II

ASSIGNMENT SHEET #2 — CALCULATE AMPACITY OF CONDUCTORS, GIVEN NUMBER OF CONDUCTORS IN RACEWAY

NAME ______________________________ SCORE ______________

The electrical technician must be able to calculate the ampacity of conductors, given various numbers in the raceway. This skill requires that the technician be able to locate and read *National Electrical Code* tables.

Use the *National Electrical Code*, Table 310-16 and Note 8 following the tables to calculate ampacity of conductors, given various numbers in a raceway. Complete the chart below using the values given for copper wire, type THW.

THW#	**Number in Raceway**	**Ampacity**	**Number in Raceway**	**Ampacity**
8	3	A.________	6	G.________
10	3	B.________	27	H.________
4	3	C.________	9	I.________
00	3	D.________	8	J.________
250 MCM	3	E.________	8	K.________
3	3	F.________	17	L.________

CONDUCTORS
UNIT II

ASSIGNMENT SHEET #3 — CALCULATE AMPACITY AND CONDUCTOR SIZES FOR SPECIFIC TYPES OF LOADS

NAME ______________________ SCORE __________

The electrical technician must be able to calculate correct ampacity and conductor size for various types of loads. This skill requires that the technician be able to locate and read *National Electrical Code* tables.

Use the *National Electrical Code,* Article 424-3(a) and (b), Article 430-22 and Tables 310-16 and 430-22(a) to calculate ampacities and conductor sizes for specific types of loads.

Full-Load Amperes	**Fixed Electric Space Heater Amperes**	**Conductor Size at 85°C**
A. 27		
B. 65		
C. 72		

Single Motor Load Amperes	**Type of Motor**	**Full-Load Motor Amperes**	**Conductor Size at 85°C**
A. 43	Elevator motor, continuous rated		
B. 90	Varying duty, 30-60 minute rated		
C. 110	Pump motor, 5 minute rated		
D. 86	Valve motor, 15 minute rated		
E. 17	Metal roll, 30-60 minute rated		

IED - 55-B

CONDUCTORS
UNIT II

ASSIGNMENT SHEET #4 — USE TABLES TO CALCULATE VOLTAGE DROPS OF SELECTED CIRCUITS

NAME ____ SCORE ________________

The *National Electrical Code* Ampacities Tables 310-16 through 310-19 are based on temperature. Voltage drops are not considered. However, industrial electricians must allow for voltage drops, especially when working with long conductor runs.

Use the formula for voltage drop and the table below to calculate voltage drops of selected circuits. Show your work.

EXAMPLE: Voltage Drop = Circuit Amperage × (Length of Run ÷ 100) × Conductor Drop

Where Circuit amperage = 45 amperes
Length of run = 1,000 feet
Conductor drop = 0.08333 volts

Voltage Drop = 45 × (1000 ÷ 100) × 0.08333
= 45 × 10 × 0.08333
= 37.49 volts

VOLTAGE DROP TABLE

Wire Size	Conductor Drop 1 Phase Volts	 3 Phase Volts
14	.4762	.4167
12	.3125	.3632
10	.1961	.1677
8	.1250	.1087
6	.08333	.0714
4	.0538	.0463
3	.0431	.0379
2	.0370	.0323
1	.0323	.0278
1/0	.0269	.0231
2/0	.0222	.0196
3/0	.0190	.0163
4/0	.0161	.0139
250MCM	.0147	.0128
300MCM	.0131	.0114
350MCM	.0121	.0106
400MCM	.0115	.0091
500MCM	.0101	.0088

ASSIGNMENT SHEET #4

A. What is the voltage drop in a 12-ampere single-phase circuit containing 83 feet of #12 wire?

Voltage drop = ______________________________

B. What is the voltage drop in a 12-ampere single-phase circuit containing 83 feet of #10 wire?

Voltage drop = ______________________________

C. What is the voltage drop in an 84-ampere three-phase circuit containing 310 feet of #3 wire?

Voltage drop = ______________________________

D. What is the voltage drop in an 84-ampere three-phase circuit containing 310 feet of #1 wire?

Voltage drop = ______________________________

ASSIGNMENT SHEET #4

E. What is the voltage drop in an 84-ampere single-phase circuit containing 310 feet of #4 wire?

Voltage drop = ____________________

F. What is the voltage drop in a 75-ampere single-phase circuit containing 100 feet of #2 wire?

Voltage drop = ____________________

G. What is the voltage drop in a 175-ampere three-phase circuit containing 65 feet of #3 wire?

Voltage drop = ____________________

H. What is the voltage drop in an 80-ampere single-phase circuit containing 150 feet of #2 wire?

Voltage drop = ____________________

CONDUCTORS
UNIT II

ASSIGNMENT SHEET #5 — SELECT PROPER TYPES OF INSULATION

NAME ______________________________ SCORE ____________

The industrial electrician must be able to select insulation according to its intended use.

PART I

Using Table 310-13 in the *National Electrical Code*, select proper insulation types for each of the following situations. Blanks may have more than one answer.

A. Boiler room where there is high humidity and high heat

____

B. Machine shop where there is cutting oil in use

____

C. Computer room with normal heat and humidity

____

D. Car wash with normal temperatures and high humidity

____

E. Commercial kitchen with high temperature and normal humidity

____

ASSIGNMENT SHEET #5

PART II

Use the *National Electrical Code*, Table 310-13 to find temperature rating in degrees centigrade and degrees Fahrenheit for each of the following insulation types, under normal uses.

	Type	°C	°F
A.	T		
B.	TW		
C.	THW		
D.	THHN		
E.	MTW (wet location)		
F.	RHH		
G.	THWN		
H.	A		
I.	ZW (dry location)		
J.	AVL		
K.	SA		
L.	MI		
M.	USE		
N.	PFA		
O.	RUW		

CONDUCTORS
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. #12 AWG

B. #8 AWG

C. #10 AWG

D. #3 AWG

E. #2 AWG

F. #250 MCM

G. #500 MCM

H. #1750 MCM

I. #4 AWG

J. #4 AWG

K. #000 AWG

Assignment Sheet #2

A. 50 amperes

B. 30 amperes

C. 85 amperes

D. 175 amperes

E. 255 amperes

F. 100 amperes

G. 40 amperes

H. 18 amperes

I. 59.5 amperes

J. 122.5 amperes

K. 178.5 amperes

L. 70 amperes

Assignment Sheet #3

Part I

A. 33.75, #10 AWG

B. 81.25, #4 AWG

C. 90, #4 AWG

ANSWERS TO ASSIGNMENT SHEETS

Part II

A. 60.2, #6 AWG

B. 135, #1 AWG

C. 93.5, #4 AWG

D. 103.2, #3 AWG

E. 16.15, #16 AWG

Assignment Sheet #4

A. 3.11 volts

B. 1.95 volts

C. 9.87 volts

D. 7.24 volts

E. 14.01 volts

F. 2.78 volts

G. 4.31 volts

H. 4.44 volts

Assignment Sheet #5

Part I

A. MTW, THW, THWN

B. MTW

C. T, TW, THHN, THW, THWN

D. TW, MTW, THW, THWN

E. THHN, MTW, THW, THWN

Part II

A. 60°C, 140°F

B. 60°C, 140°F

C. 75°C, 167°F

D. 90°C, 194°F

E. 60°C, 140°F

F. 90°C, 194°F

G. 75°C, 167°F

H. 200°C, 392°F

ANSWERS TO ASSIGNMENT SHEETS

I. 90°C, 194°F

J. 110°C, 230°F

K. 90°C, 194°F

L. 85°C, 185°F

M. 75°C, 167°F

N. 90°C, 194°F

O. 60°C, 140°F

CONDUCTORS
UNIT II

JOB SHEET #1 — USE A FISH TAPE TO INSTALL WIRE IN CONDUIT

I. Equipment and materials

  A. 60 feet of conduit

  B. Steel fish tape, 100 or 200 feet long

  C. 500 feet of #10 THHN wire

  D. Pouch tools

  E. Wire-pulling compound

II. Procedure

(NOTE: Work in teams of three or more.)

  A. Cut six 70-foot pieces of #10 THHN

  B. Lay out wire at feed-in end of conduit run, straight enough to be installed without kinking or becoming tangled

  C. Push fish tape into opposite end of conduit run

  (NOTE: If it is difficult to push the tape around the last 90-degree bend, grip the fish tape with lineman's pliers about 1 or 2 inches from the end and push; or while pushing on fish tape, have someone tap on conduit near the 90-degree bend where the difficulty seems to be.)

  D. Skin back about 5 inches of insulation on each wire at fish-tape-connection end

  E. Attach wires to fish-tape eye

  (NOTE: Squeeze bent wires, making joint the smallest size practical, and tape. Apply tape tightly from conductor toward fish tape. Taping tightly leaves the tape with no leading edges to make pulling more difficult.)

  F. Lubricate the connection

  G. Pull fish tape very slowly at first to get the connection into the conduit

  (NOTE: The feed-in person can help by pushing slightly on conductors. When pulling fish tape, exert a smooth steady pull; do not jerk.)

JOB SHEET #1

H. Pull until conductor is through conduit at appropriate length

(NOTE: Have instructor evaluate your work.)

I. Clean work area; put away all tools and equipment

CONDUCTORS
UNIT II

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with conductors to their correct definitions. Write the correct numbers in the blanks. Definitions are continued on the following page.

_____a. Conductor made of copper

_____b. Assigning colors to conductors based on their uses

_____c. Aluminum conductor with an outer coating of copper metallurgically bonded to aluminum core

_____d. Conductor encased in material of composition and thickness recognized by the *National Electrical Code* as electrical insulation

_____e. Conductor encased in material of composition and thickness not recognized by the *National Electrical Code* as electrical insulation

_____f. Current-carrying capacity of conductors; expressed in amperes

_____g. Long tape of steel, nylon, or other material used to push or pull a conductor into a raceway

_____h. Compound of soap and other substances used to lubricate conductors being pulled or pushed into a raceway

_____i. Manual or motor-powered mechanical device used to pull conductors into a raceway

_____j. Movable rack used to hold one or more reels of wire so that wire can be easily pulled off reel and fed into raceway

_____k. Strong rope of nylon or other substance used to pull heavy conductors into raceways

1. Copper wire
2. Power fish-tape system
3. Copper-clad aluminum
4. Ampacity
5. Cable benders
6. Covered
7. Wire dispenser
8. Insulated
9. Pull rope
10. Aluminum wire
11. Winch
12. Color coding
13. Wire-pulling compound
14. Fish tape
15. Voltage drop

TEST

_____l. Vacuum or air pressure system for installing a pull cord in a raceway in order to pull in the heavy pull rope for heavy and long pulls

_____m. Mechanical or hydraulic devices used to bend heavy conductors in panels and junction boxes

_____n. Conductor made of aluminum

_____o. Voltage lost in forcing load amperes through conductors

2. List factors that determine type and size of conductors.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

3. Select from the following list characteristics of good connections. Write an "X" in the blank before each correct answer.

_____a. Do not place copper and aluminum in direct contact

_____b. Provide full contact

_____c. Are made with magnetic screwdriver

_____d. Are tight

_____e. Require no tools for installation

_____f. Are clean

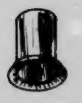
_____g. Provide quick disconnect

_____h. Show bright terminal connection

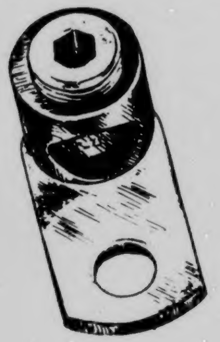
_____i. Are strong

TEST

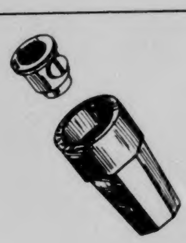
4. Label the following types of connectors, terminals and lugs. Write the correct names in the blanks.



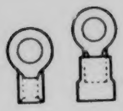
a. ______________________________



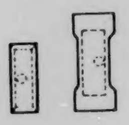
b. ______________________________



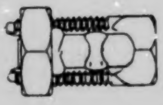
c. ______________________________



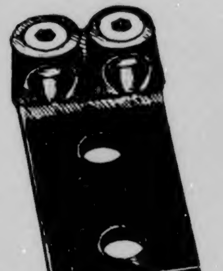
d. ______________________________



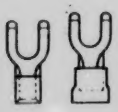
e. ______________________________



f. ______________________________

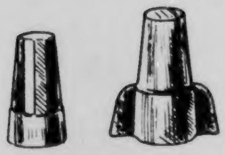


g. ______________________________

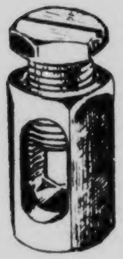


h. ______________________________

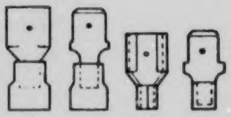
TEST



i. ______________________



j. ______________________



k. ______________________

5. Identify types of insulation, given their correct code letters, applications, and characteristics. Write your answers in the correct blanks to complete the chart below.

Insulation Name	Code Letters	Application	Characteristics
a.	THW	Dry and wet locations Special applications within electric discharge lighting equipment; limited to 1,000 open-circuit volts or less (size 14-8 only as permitted in Section 410-31)	Flame retardant, moisture and heat resistant
b.	THWN	Dry and wet locations	Flame retardant, moisture and heat resistant
c.	T	Dry locations	Flame retardant
d.	TW	Dry and wet locations	Flame retardant, moisture resistant
e.	THHN	Dry locations	Flame retardant, heat resistant
f.	MTW	Machine tool wiring in wet locations as permitted in NFPA Standard No. 79 (See Article 670) Machine tool wiring in dry locations as permitted in NFPA Standard No. 79 (See Article 670)	Flame retardant, moisture, heat, and oil resistant

TEST

(NOTE: Test questions 6 through 11 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

6. Select conductors for various ampacities and temperatures.
7. Calculate ampacity of conductors, given number of conductors in raceway.
8. Calculate ampacity and conductor sizes for specific types of loads.
9. Use tables to calculate voltage drops of selected circuits.
10. Select proper types of insulation.
11. Demonstrate the ability to use a fish tape to install wire in conduit.

CONDUCTORS
UNIT II

ANSWERS TO TEST

1.
   a. 1
   b. 12
   c. 3
   d. 8
   e. 6
   f. 4
   g. 14
   h. 13
   i. 11
   j. 7
   k. 9
   l. 2
   m. 5
   n. 10
   o. 15

2.
   a. Full-load amperes
   b. Number of conductors in raceway
   c. Type load to be served
   d. Length of run
   e. Ambient temperature encountered
   f. Voltage

3. a, b, d, f, i

4.
   a. Crimp sleeve connector
   b. Single terminal
   c. Setscrew lug
   d. Ring lugs
   e. Crimp-type butt connectors
   f. Split-bolt lug
   g. Twin terminal
   h. Spade connectors
   i. Wire-nut lugs
   j. Service-entrance lug
   k. Quick-disconnect connectors

5.
   a. Moisture- and heat-resistant thermoplastic
   b. Moisture- and heat-resistant thermoplastic
   c. Thermoplastic

ANSWERS TO TEST

- d. Moisture-resistant thermoplastic
- e. Heat-resistant thermoplastic
- f. Moisture-, heat-, and oil-resistant thermoplastic

6. Evaluated to the satisfaction of the instructor

7. Evaluated to the satisfaction of the instructor

8. Evaluated to the satisfaction of the instructor

9. Evaluated to the satisfaction of the instructor

10. Evaluated to the satisfaction of the instructor

11. Performance skills evaluated to the satisfaction of the instructor

ELECTRICAL RACEWAYS
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to bend, cut, ream, and install ½-inch electrical metallic tubing and rigid nonmetallic conduit. The student will show this knowledge by completing the job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Define *raceway.*
2. Name types of electrical raceways in common use.
3. State uses and fittings for rigid metal conduit and intermediate metal conduit.
4. State uses and fittings for electrical metallic tubing (EMT).
5. State uses and fittings for rigid nonmetallic conduit (PVC).
6. State uses and fittings for flexible metal conduit.
7. State uses and fittings for liquidtight flexible conduit.
8. State uses and fittings for surface raceways (Wire Mold).
9. State uses and fittings for busways.
10. Identify conduit bodies commonly used in industry.
11. Identify types of conduit bends.
12. Identify conduit support methods.
13. Demonstrate the ability to
    a. Bend, cut, ream, and thread ½-inch rigid metal conduit.
    b. Install setscrew fittings on ½-inch EMT.
    c. Cut and ream EMT.
    d. Install a compression fitting on a piece of EMT.
    e. Bend EMT stub-ups.

OBJECTIVE SHEET

f. Make back-to-back bends on 1/2-inch EMT.

g. Make offset bends on 1/2-inch EMT.

h. Bend a four-point saddle on 1/2-inch EMT.

i. Bend and install 1/2-inch EMT.

j. Cut, ream, and install coupling on 1/2-inch PVC.

ELECTRICAL RACEWAYS
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

A. Obtain copies of "The Bending System" by Republic Steel Corporation for each student. Copies should be available through your local electrical supply house.

(NOTE: This booklet covers in detail EMT bending by hand.)

B. Arrange for a class demonstration of conduit bending by an experienced electrician.

C. Review Job Sheet #4 in Unit II, "Power Equipment." Explain to students that they need to know how to measure, cut, and thread pipe when working with rigid and intermediate metal conduit.

D. Provide students with objective sheet.

E. Discuss unit and specific objectives.

F. Provide students with information and job sheets.

G. Discuss information and job sheets.

1. Discuss definition of *raceway* and types of raceways in common use, using Information Sheet, Sections I and II. Show students samples of different conduit: EMT, rigid, PVC, short pieces of Greenfield, and liquidtight.

2. Discuss uses and fittings for rigid metal conduit and intermediate metal conduit, using Information Sheet, Section III and Transparency #1. Have students review Articles 345 and 346 in the *National Electrical Code.* Job Sheet #1 will help the student understand the process of threading and assembling rigid metal conduit.

3. Discuss the uses and fittings for electrical metallic tubing, using Information Sheet, Section IV, Transparency #2, and Job Sheets #2 through #9. Have students review Article 348 in the *National Electrical Code.* Show students the difference between EMT and rigid metal conduit by pointing out the different thicknesses of the walls.

4. Discuss the uses and fittings for rigid nonmetallic conduit, using Information Sheet, Section V, Transparency #3, and Job Sheet #10. Have students review Article 347 in the *National Electrical Code.* Explain to students the benefits of using conduit that is not corrosive and is impervious to such things as vapors and chemicals that normally corrode steel pipe. Also explain the limitations of rigid nonmetallic conduit because of its susceptibility to bend during intense heat. Point out places where it would be advisable to use rigid nonmetallic conduit: furnace rooms, boiler rooms, and other places where heat may be a problem.

SUGGESTED ACTIVITIES

5. Discuss uses and fittings for flexible metal conduit, using Information Sheet, Section VI and Transparency #4. Have students review Article 350 in the *National Electrical Code* so that they understand the restrictions on $^3/_8$-inch flexible metal conduit. Some city codes also restrict the use of flexible metal conduit regardless of size. Students should be made aware of these restrictions, as well as the grounding requirements specified in the *Code*.

6. Discuss the uses and fittings for liquidtight flexible conduit, using Information Sheet, Section VII and Transparency #5. Have students review Article 351 in the *National Electrical Code*. Show students samples to help them see that liquidtight conduit is very similar to flexible metal conduit, but simply has a waterproof, weatherproof jacket over an inner flexible metallic or nonmetallic core. Give the students some examples of where liquidtight conduit may be used: outside, for hooking up air conditioner disconnects, equipment on roofs, equipment in carwashes.

7. Discuss the uses and fittings for surface raceways and Wire Molds, using Information Sheet, Section VIII and Transparency #6. Have students review Article 352 in the *National Electrical Code*. It is possible that within your own building there are areas in which surface raceways or Wire Mold has been used. Make a tour of the building with your students. Explain why surface raceways or Wire Molds are used after construction has been completed: to add or move circuits from one place to another without having to break open finished walls.

8. Discuss uses and fittings for busways, using Information Sheet, Section IX and Transparencies #7 and #8. Have students review Article 364 in the *National Electrical Code*. If busways are not present in your installation, arrange a field trip to a local factory that uses busways for main power distribution throughout the plant. Point out the different fittings that are available and the adaptability of a busway to provide power at numerous places with little difficulty.

9. Discuss the differences in conduit bodies commonly used in industry, and the proper way to identify and name them. Use Information Sheet, Section X and Transparency #9. Discuss with the students possible uses for each conduit body, and explain why they are helpful for such things as making pull points or taking conduit around sharp corners.

10. Discuss the various types of conduit bends, using Information Sheet, Section XI. Show students examples of the different bends.

11. Discuss conduit support methods, using Information Sheet, Section XII and examples of straps, brackets, clips, and clamps illustrated in this section. Tour your facility to show students the various ways that conduit is supported.

H. Give test.

SUGGESTED ACTIVITIES

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Transparency masters

      1. TM #1 — Types of Raceways and Fittings

      2. TM #2 — Types of Raceways and Fittings (Continued)

      3. TM #3 — Types of Raceways and Fittings (Continued)

      4. TM #4 — Types of Raceways and Fittings (Continued)

      5. TM #5 — Types of Raceways and Fittings (Continued)

      6. TM #6 — Liquidtight Flexible Metal Conduit

      7. TM #7 — Busways

      8. TM #8 — Busway Connections

      9. TM #9 — Conduit Bodies Commonly Used in Industry

   E. Job sheets

      1. Job Sheet #1 — Bend, Cut, Ream, and Thread 1/2-Inch Rigid Metal Conduit

      2. Job Sheet #2 — Install Setscrew Fittings on 1/2-Inch EMT

      3. Job Sheet #3 — Cut and Ream EMT

      4. Job Sheet #4 — Install a Compression Fitting on a Piece of EMT

      5. Job Sheet #5 — Bend EMT Stub-Ups

      6. Job Sheet #6 — Make Back-to-Back Bends on 1/2-Inch EMT

      7. Job Sheet #7 — Make Offset Bends on 1/2-Inch EMT

      8. Job Sheet #8 — Bend a Four-Point Saddle on 1/2-Inch EMT

      9. Job Sheet #9 — Bend and Install 1/2-Inch EMT

      10. Job Sheet #10 — Cut, Ream, and Install Coupling on 1/2-Inch PVC

SUGGESTED ACTIVITIES

F. Test

G. Answers to test

III. Unit references

   A. *Caddy Fasteners for the Construction Industry.* Cleveland, Ohio: ERICO Products, Inc., n.d.

   B. Croft, Terrell, et al. *American Electrician's Handbook,* 9th ed. New York: McGraw-Hill Book Company, 1970.

   C. *Cutler-Hammer Construction Industry Catalog,* NJ200. Pittsburgh, Pennsylvania: Cutler-Hammer Company, n.d.

   D. *Electric Raceways, Bending Tools and Accessories.* Cleveland, Ohio: Republic Steel Corporation, n.d.

   E. *Electrunite EMT Bending System.* Cleveland, Ohio: Republic Steel Corporation, n.d.

   F. *Kindorf Structural Support, Surface Raceway, Metal Framing.* Pittsburgh, Pennsylvania:Midland-Ross Corporation, Electrical Products Division, 1980.

   G. National Fire Protection Association. *National Electrical Code 1984.* Quincy, Massachusetts: National Fire Protection Association, 1983.

   H. Taylor, Mark. *Residential Wiring.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1978.

ELECTRICAL RACEWAYS
UNIT III

INFORMATION SHEET

I. Raceway — An enclosed channel designed expressly for holding wires, cables, or busbars, with additional functions as permitted in the *National Electrical Code*

(NOTE: Raceways may be of metal or insulating material, and the term includes rigid metal conduit, rigid nonmetallic conduit, intermediate metal conduit, liquidtight flexible metal conduit, flexible metallic tubing, flexible metal conduit, electrical nonmetallic tubing, electrical metallic tubing, underfloor raceways, cellular metal floor raceways, surface raceways, wireways, and busways.)

II. Types of electrical raceways in common use

A. Rigid metal conduit and intermediate metal conduit

B. Electrical metallic tubing (EMT)

C. Rigid nonmetallic conduit (PVC)

D. Flexible metal conduit

E. Liquidtight flexible metallic conduit

F. Surface raceways (Wire Mold)

G. Busways

(NOTE: There are numerous other types of raceways for use in special situations. These situations and raceways may be found in Chapter 3 of the *National Electrical Code*.)

III. Uses and fittings for rigid metal conduit and intermediate metal conduit

A. Typical uses — In all locations and all atmospheric conditions

(NOTE: When subjected to corrosive influences, rigid and intermediate metal conduits must have an enamel coating as required by the *National Electrical Code*.)

B. Standard fittings

1. Threaded couplings

2. Locknuts

3. Threadless couplings

INFORMATION SHEET

4. Threadless connectors
5. Bushings
6. Factory elbows

IV. Uses and fittings for electrical metallic tubing (EMT)

A. Typical uses

1. For exposed work
2. For concealed work
3. In wet locations
4. In dry locations

(NOTE: For restrictions of usage, refer to *NEC*, Article 348.)

B. Standard fittings

1. Setscrew connectors
2. Setscrew couplings
3. Compression connectors
4. Compression couplings
5. Locknuts
6. Bushings

V. Uses and fittings for rigid nonmetallic conduit (PVC)

A. Typical uses

1. For concealed work in walls, floors, and ceilings
2. In corrosive conditions
3. In cinder fill
4. In wet locations

EXAMPLES: Dairies, laundries, canneries, and where walls are washed regularly

5. For exposed locations not subject to physical damage
6. For underground locations

INFORMATION SHEET

B. Standard fittings

1. Couplings
2. Male connectors
3. Female connectors
4. Factory elbows
5. Locknuts

VI. Uses and fittings for flexible metal conduit

A. Typical uses

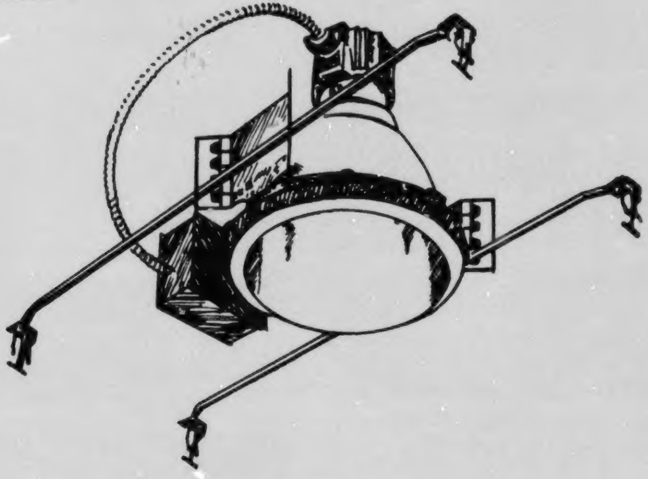
(NOTE: Flexible metal conduit is commonly called *Greenfield.* **Uses not approved for flexible metal conduit are wet locations, hoistways, storage battery rooms, hazardous locations, locations where rubber-covered conductors are subjected to oils or other substances that destroy rubber, underground, and embedded in concrete.)**

1. For connecting commercial and industrial lighting fixtures
2. For raceways between motors and motor controllers (Figure 1)

   (NOTE: $^3/_8$-inch Greenfield may be run no longer than 6 feet. **Any size run longer than 6 feet must have a ground wire.)**

   EXAMPLE:

FIGURE 1



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INFORMATION SHEET

B. Standard fittings

1. Straight connectors
2. 90-degree connectors
3. Flex-to-pipe adapters

VII. Uses and fittings for liquidtight flexible conduit

A. Typical uses

(NOTE: See *NEC,* Article 351. Liquidtight flexible metallic conduit is not permitted where subject to physical damage and where temperature of conductors or atmosphere exceeds temperature of liquidtight jacket.)

1. In locations where conditions require flexibility and protection from liquids, vapors, or solids

   EXAMPLES: Motors in milk plant, motors in commercial fertilizer plant

2. In certain hazardous locations

   EXAMPLES: Gasoline pump, transformer vault

B. Standard fittings

1. Straight connectors
2. 90-degree connectors
3. Pipe adapters

VIII. Uses and fittings for surface raceways (Wire Mold)

A. Typical uses

1. On surface of finished walls
2. Only inside for NEMA 1 conditions

B. Standard fittings

1. Elbows
2. Box adapters
3. Conduit adapters

INFORMATION SHEET

IX. Uses and fittings for busways

  A. Typical uses

    1. In industrial plants

    2. For power distribution

    3. In assembly lines

  B. Standard fittings

    1. Plug-in busways

    2. Switch adapters

    3. Tees

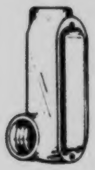
    4. End caps

    5. Elbows

X. Conduit bodies commonly used in industry (Figures 2-6)

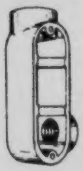
  A. LL condulet

FIGURE 2



  B. LR condulet

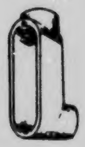
FIGURE 3



INFORMATION SHEET

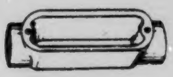
C. LB condulet

FIGURE 4



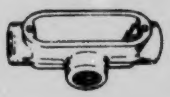
D. C-condulet

FIGURE 5



E. T-condulet

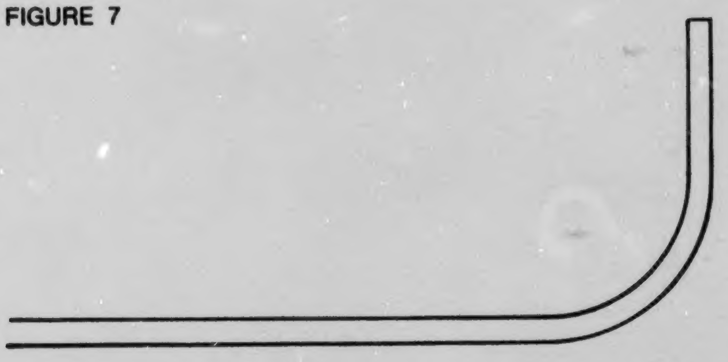
FIGURE 6



XI. Types of conduit bends (Figures 7-11)

A. 90-degree stub-up

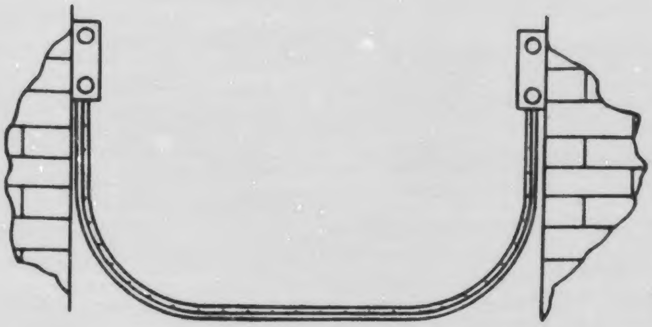
FIGURE 7



INFORMATION SHEET

B. 90-degree back-to-back

FIGURE 8



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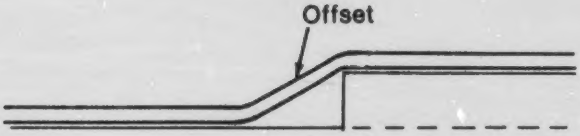
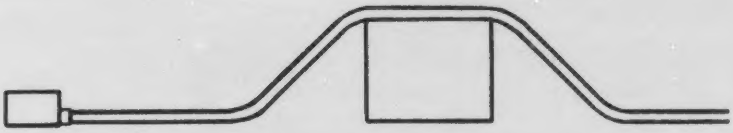
C. Offset

FIGURE 9



D. Four-point saddle

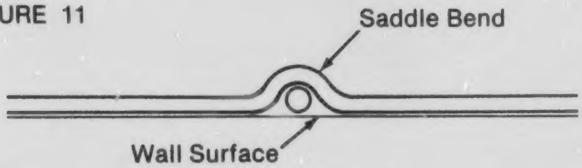
FIGURE 10



INFORMATION SHEET

E. Three-point saddle

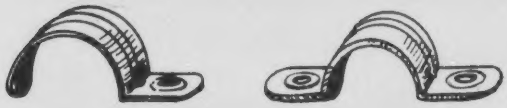
FIGURE 11



XII. Conduit support methods (Figures 12-20)

A. One- or two-hole straps

FIGURE 12



B. Wall support brackets

FIGURE 13

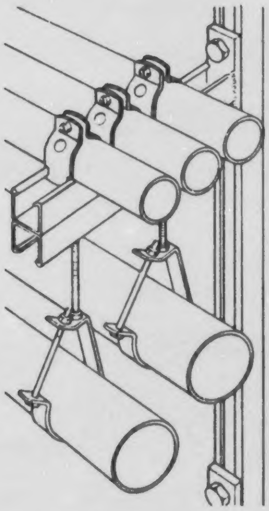
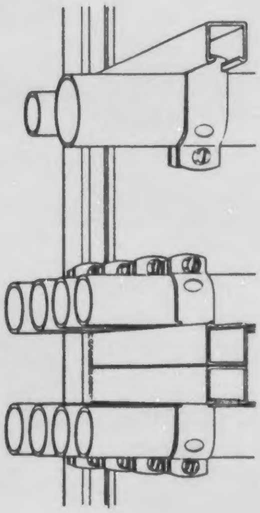


FIGURE 14



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INFORMATION SHEET

C. Beam clamps and hanger rod supports

FIGURE 15

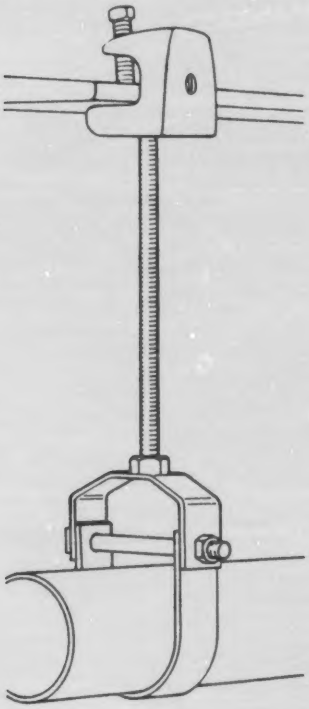
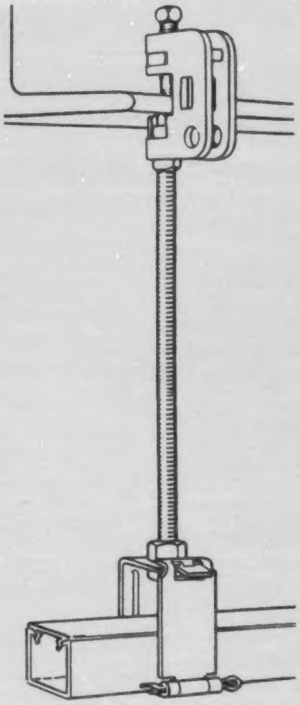


FIGURE 16



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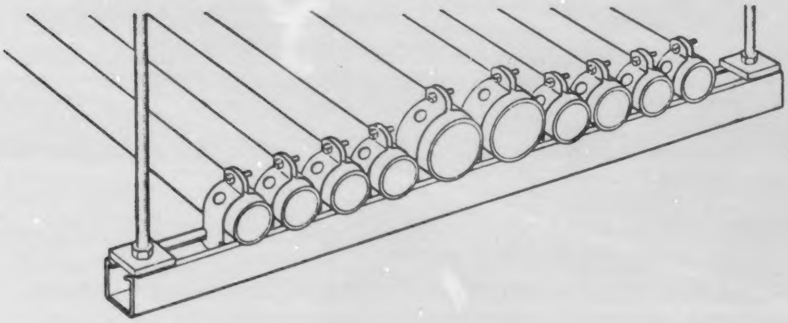
INFORMATION SHEET

D. Conduit supports

(NOTE: These supports are frequently referred to as *Mineralac straps.*)

FIGURE 17



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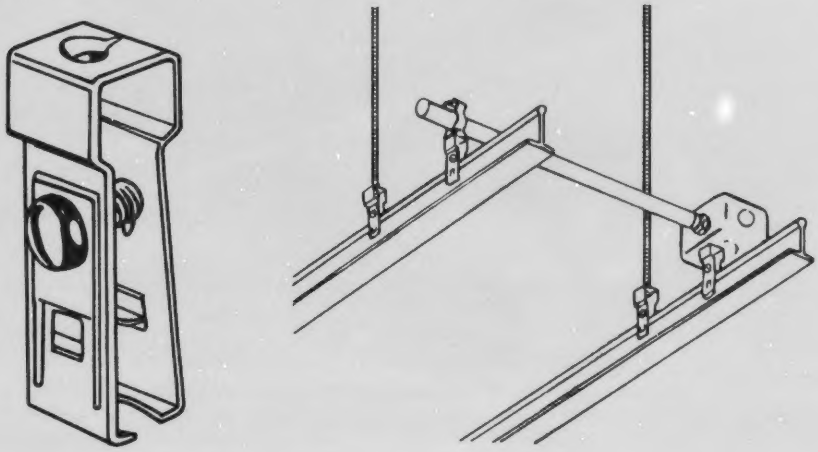
INFORMATION SHEET

E. T-bar support clips

(NOTE: These clips must also have a Mineralic strap when used with conduit.)

FIGURE 18



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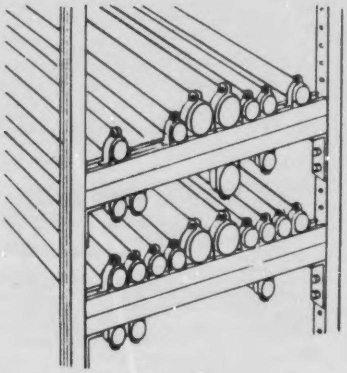
F. Frame assembly

FIGURE 19



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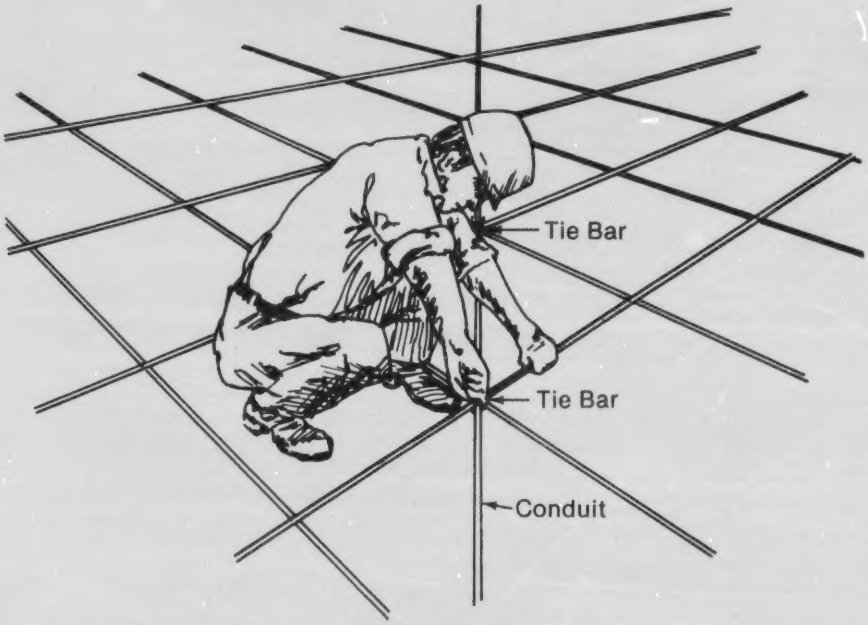
INFORMATION SHEET

G. Tie-wires or clamps for installations in concrete work

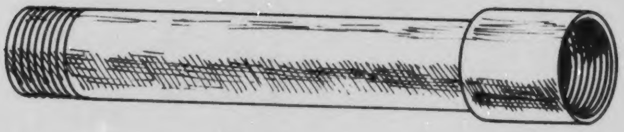
(CAUTION: When being poured, concrete exerts heavy pressures on conduit that has been installed. Unless conduit is *securely* fastened in place, it will probably be moved away from the desired location [out from a wall, for example].)

FIGURE 20

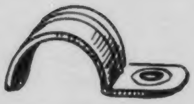


Types of Raceways and Fittings

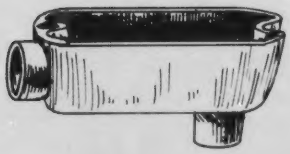
Rigid Metal Conduit



Metal Conduit and Coupling



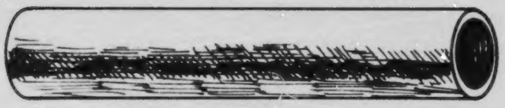
One-Hole Strap



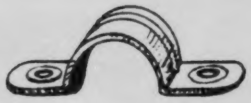
Conduit Body

Types of Raceways and Fittings
(Continued)

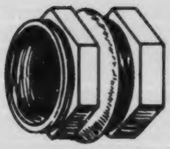
Electrical Metallic Tubing



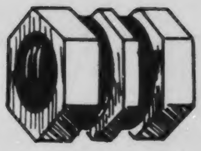
EMT



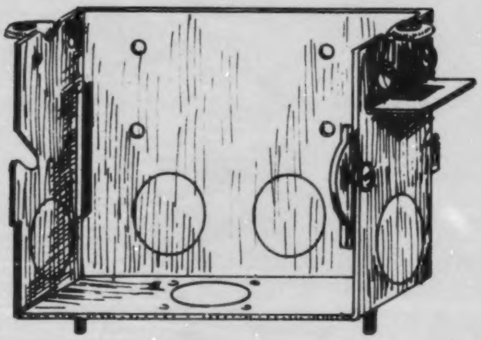
Two-Hole Strap



Raintight EMT Connector



Raintight EMT Coupling

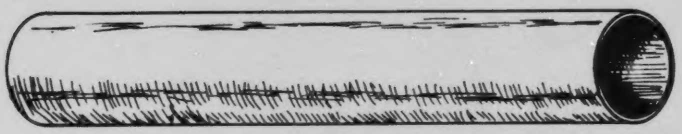


Device Box for Conduit

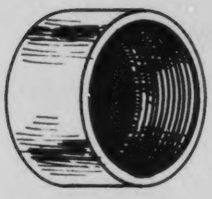
Types of Raceways and Fittings

(Continued)

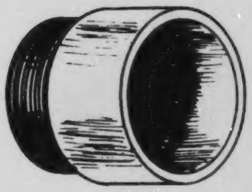
PVC (Polyvinyl Chloride)



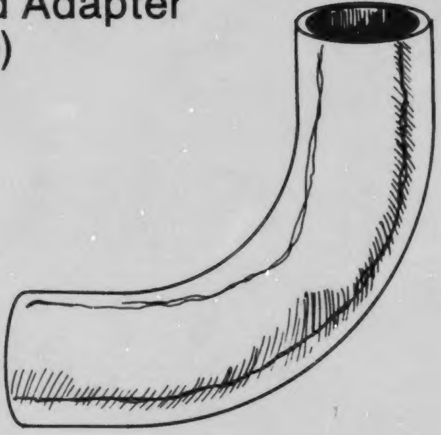
PVC



PVC to Threaded Adapter
(Female)



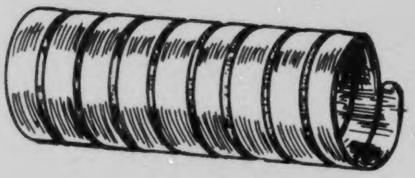
PVC to Threaded Adapter
(Male)



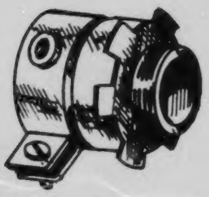
PVC 90° Bend

Types of Raceways and Fittings
(Continued)

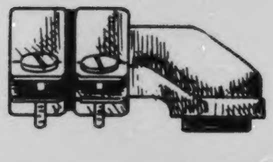
Flexible Metal Conduit



Flexible Metal Conduit



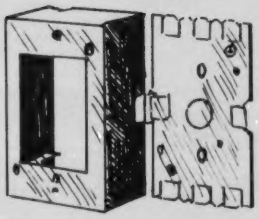
Straight Connector



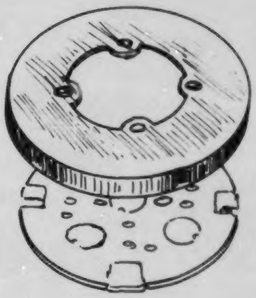
90° Connector

Types of Raceways and Fittings
(Continued)

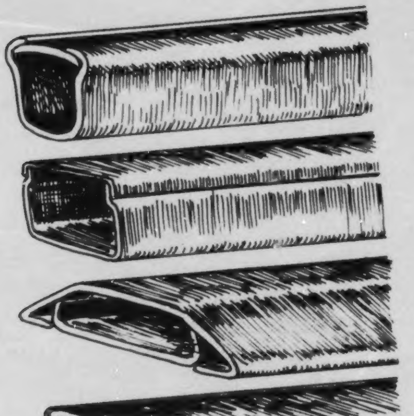
Surface Raceways



Surface Device Box

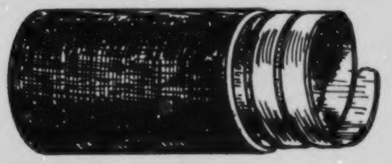


Surface Lighting Outlet

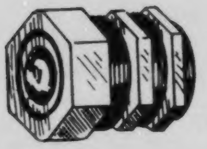


Surface Raceways

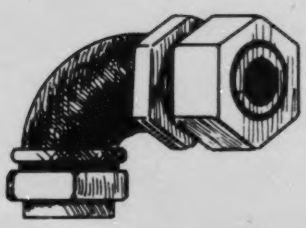
Liquidtight Flexible Metal Conduit



Liquidtight Flexible Metal Conduit

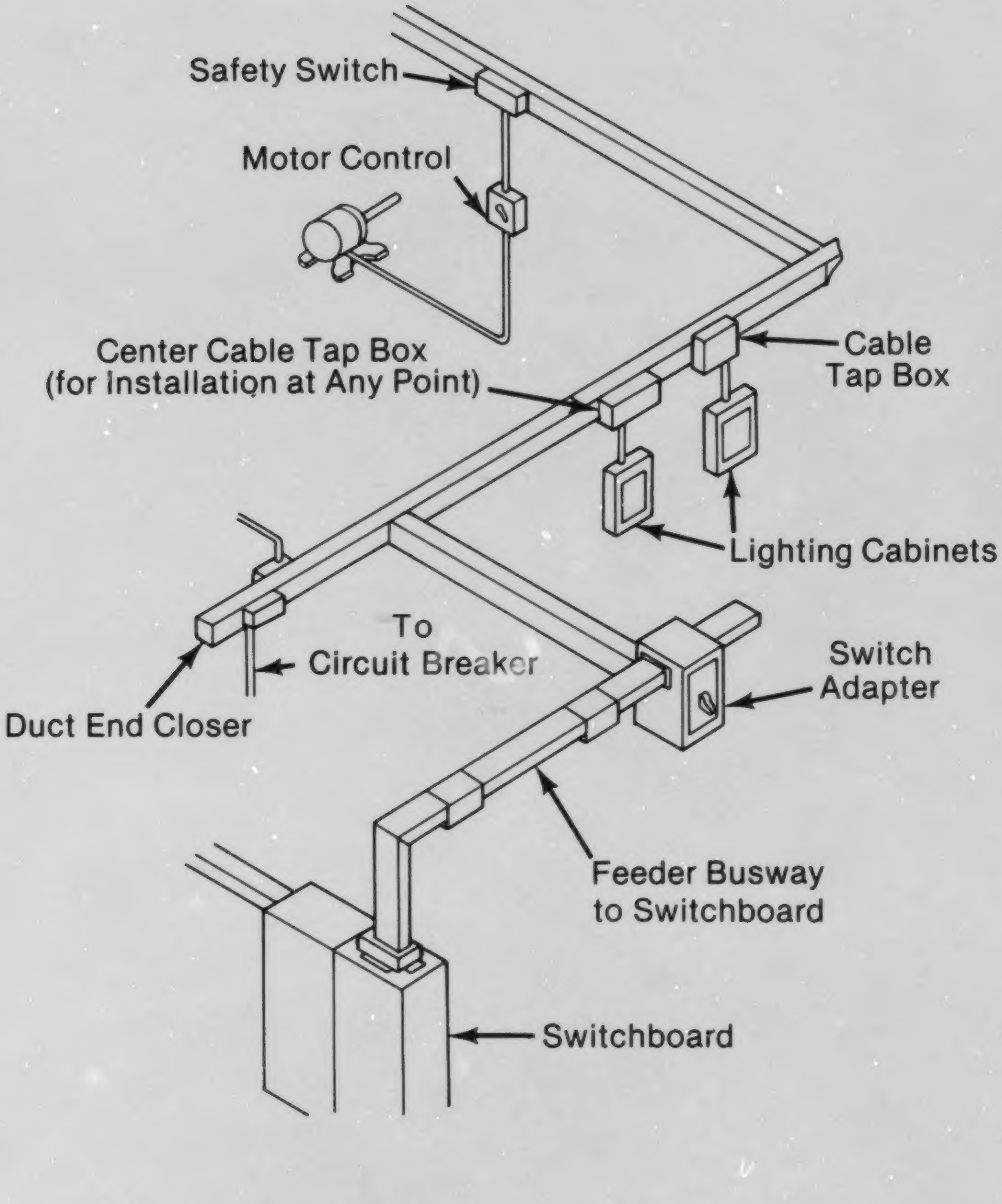


Liquidtight Connector

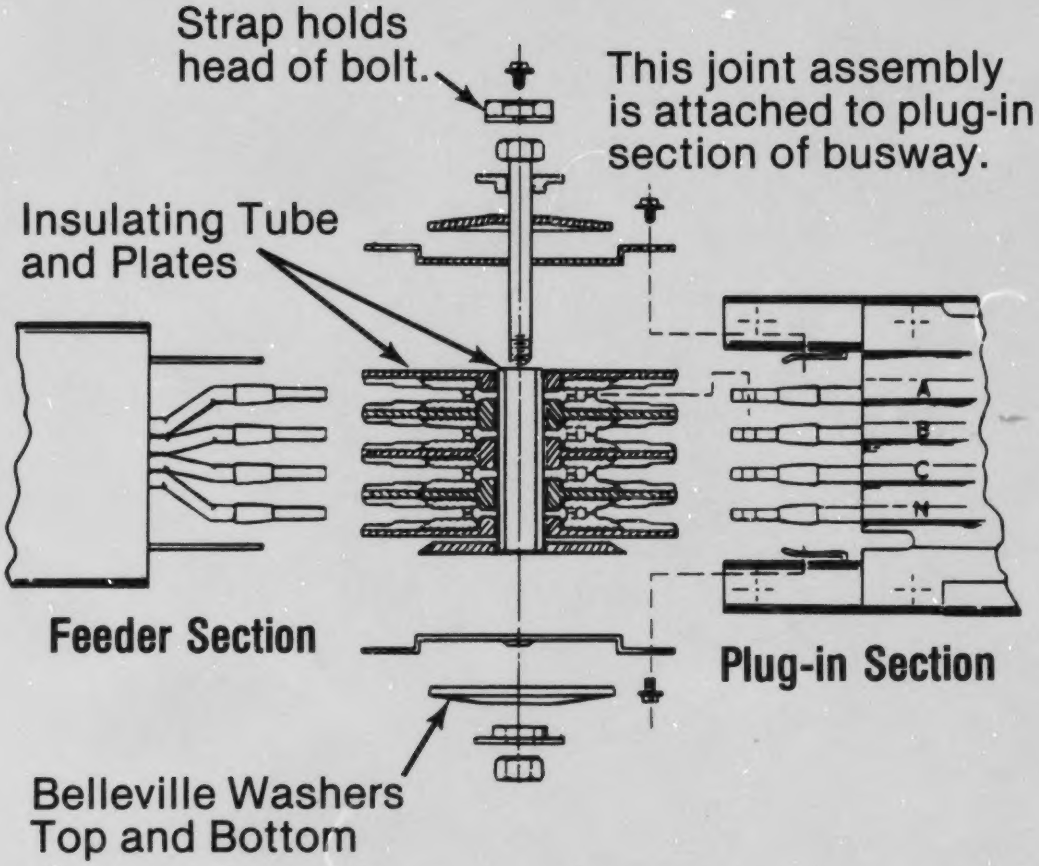


90° Liquidtight Connector

Busways


Safety Switch
Motor Control
Center Cable Tap Box
(for Installation at Any Point)
Cable
Tap Box
Lighting Cabinets
To
Circuit Breaker
Duct End Closer
Switch
Adapter
Feeder Busway
to Switchboard
Switchboard

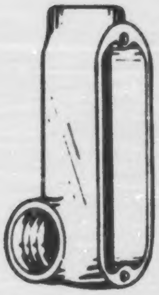
Busway Connections


Strap holds head of bolt.
This joint assembly is attached to plug-in section of busway.
Insulating Tube and Plates
A
B
C
N
Feeder Section
Plug-in Section
Belleville Washers Top and Bottom

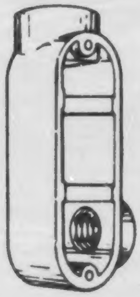
One Bolt Joint Assembly

Used with permission of Cutler-Hammer Products/Eaton Corporation.

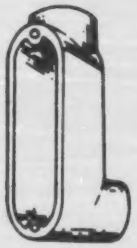
Conduit Bodies Commonly Used in Industry



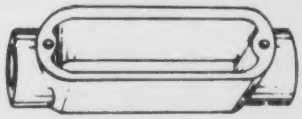
LL Condulet



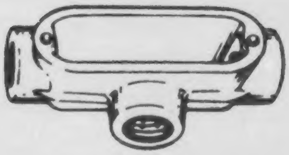
LR Condulet



LB Condulet



C-Condulet



T-Condulet

ELECTRICAL RACEWAYS
UNIT III

JOB SHEET #1 — BEND, CUT, REAM AND THREAD 1/2-INCH RIGID METAL CONDUIT

I. Equipment and materials

- A. Eye protection
- B. Hacksaw
- C. 10-foot piece of 1/2-inch rigid metal conduit
- D. 3/4-inch EMT bender with handle
- E. Reaming tool
- F. 1/2-inch conduit pipe die
- G. Cutting oil
- H. Hickey's pipe vise
- I. Measuring tape and marking pencil

II. Procedure

- A. Put on eye protection
- B. Measure and mark conduit for 18-inch stub-up

  (NOTE: Check 3/4-inch EMT bender for take up.)
- C. Place bender on conduit with "B" on bend mark
- D. Bend conduit, holding *heavy* foot pressure on bender
- E. Use hacksaw to cut off stub-up and 90-degree bend
- F. Place cut off piece of conduit in vice for threading
- G. Ream inside ends of conduit
- H. Thread end of stub, using 1/2-inch conduit pipe die and plenty of cutting oil
- I. Remove die and examine threads

  (NOTE: If die was good and an adequate amount of cutting oil was used, the threads should be smooth with sharp ridges.)

JOB SHEET #1

J. If threads are ragged, cut them off and repeat steps H and I

(NOTE: Show work to instructor for evaluation and comments.)

K. Clean work area; return equipment and materials to proper storage

ELECTRICAL RACEWAYS
UNIT III

JOB SHEET #2 — INSTALL SETSCREW FITTINGS ON ½-INCH EMT

I. Equipment and materials

- A. ½-inch setscrew fittings, couplings and connectors

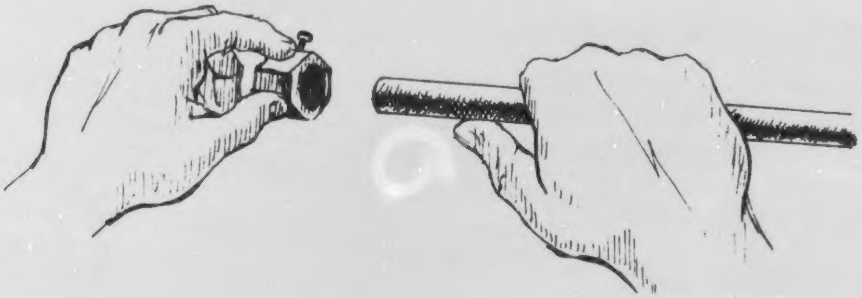
  (NOTE: For this job sheet, both connectors and couplings are needed.)
- B. ½-inch EMT
- C. Flatbladed screwdriver, medium-sized
- D. Eye protection

II. Procedure

(NOTE: Tubing should be reamed and should have a square-cut end.)

- A. Put on eye protection
- B. Pick up connector, and hold it in your dominant hand
- C. Pick up tubing with other hand
- D. Slide connector onto tubing until it bottoms (Figure 21)

FIGURE 21

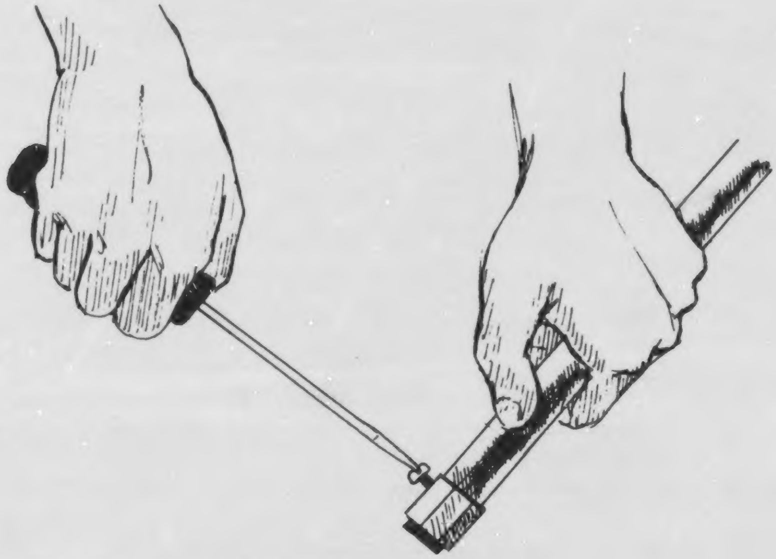


JOB SHEET #2

E. Secure screw with screwdriver (Figure 22)

(CAUTION: Keep hand holding tubing away from the connector to avoid getting jabbed if the screwdriver slips. Do not overtighten setscrew.)

FIGURE 22



F. Install setscrew connector and coupling

G. Remove setscrew connector and coupling

H. Practice installation and removal by repeating steps B through G at least two times

I. Clean work area; return equipment and materials to proper storage

ELECTRICAL RACEWAYS
UNIT III

JOB SHEET #3 — CUT AND REAM EMT

I. Equipment and materials

A. Pouch tools

B. Hacksaw

C. Pieces of EMT saved from Job Sheet #1

D. Eye protection

II. Procedure

(NOTE: This job sheet deals with small EMT; however, the same careful cutting and reaming must be applied to larger EMT encountered in industrial wiring.)

A. Examine the insides of the pieces of EMT you cut off with a hacksaw in Job Sheet #1

(NOTE: Numerous small bits of metal on the inside must be cleaned out.)

B. Put on eye protection

C. Place the long-nose pliers jaw inside the tubing

D. Grip pliers lightly, moving them around the tubing; observe how the pliers knock off small burrs or bits of metal

E. Use hacksaw to cut off a piece of tubing

F. With your finger, very carefully feel the knife-sharp ridge inside the tubing

G. Remove the sharp edge with reamer

(NOTE: These interior sharp edges can damage the insulation on the conductors when the conductors are pulled into the tubing and they can cut through insulation as the wires move, as in cases of short circuits. Often electricians fail to remove these sharp edges when using tubing cutters; consequently, many contractors and some cities do not permit the tubing cutter on the job.)

H. Practice cleaning the inside burrs from at least ten pieces of tubing that have been cut with a hacksaw

(NOTE: Show your work to the instructor for evaluation and comments.)

I. Clean work area; return equipment and materials to proper storage

ELECTRICAL RACEWAYS
UNIT III

JOB SHEET #4 — INSTALL A COMPRESSION FITTING ON A PIECE OF EMT

I. Equipment and materials

A. ½-inch compression-type fitting

B. ½-inch EMT

C. 2 pairs groove-joint pliers

(NOTE: Two adjustable wrenches, or one wrench and one pair of pliers will also suffice.)

D. Eye protection

II. Procedure

(NOTE: The EMT should have straight, even ends.)

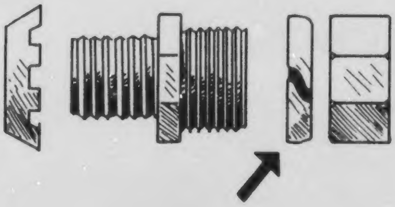
A. Put on eye protection

B. Pick up connector, and hold it in your nondominant hand for the next two steps

C. Remove compression nut and ring

D. Install nut and then compression ring on tubing (Figure 23)

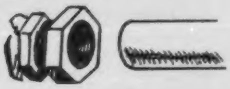
FIGURE 23



JOB SHEET #4

E. Slide fitting onto tubing until it bottoms (Figure 24)

FIGURE 24

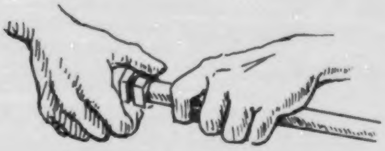


F. Slide compression ring and nut to body of fitting, and turn to engage threads

G. Tighten compression nut by hand (Figure 25)

(NOTE: Fitting may be removed and reinstalled when only hand-tight, but probably will not be removable after tightening with pliers as in step H.)

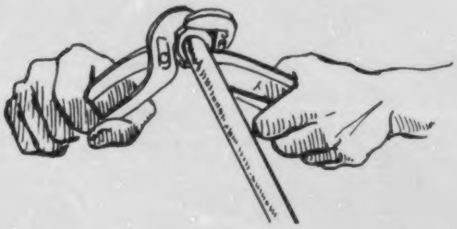
FIGURE 25



H. Tighten fittings with pliers or adjustable wrenches (Figure 26)

(CAUTION: Use care. Overtightening the smaller trade-sized fittings can cause threads to strip or nuts to crack.)

FIGURE 26



(NOTE: Show work to instructor for evaluation and comments.)

I. Clean work area; return equipment and materials to proper storage.

ELECTRICAL RACEWAYS
UNIT III

JOB SHEET #5 — BEND EMT STUB-UPS

I. Equipment and materials

- A. Measuring tape and marking pencil
- B. ½-inch EMT bender with handle
- C. 10-foot piece of ½-inch EMT
- D. Hacksaw
- E. Eye protection

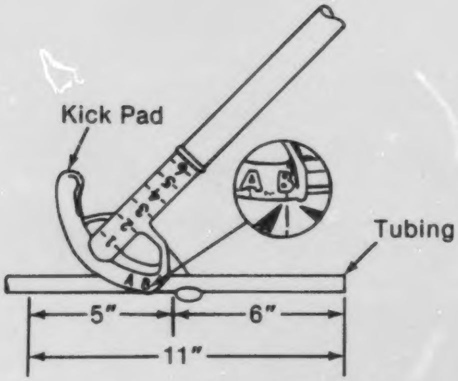
II. Procedure

(NOTE: All benders are not marked alike. Check your bender, and use measurements given for it.)

- A. Measure and mark tubing 11 inches from end to be bent
- B. Subtract 5 inches from mark made in step A; mark this measurement

  (NOTE: This measurement varies for each size tubing.)
- C. Put on eye protection
- D. Place conduit bender on tubing in position to bend toward end of tubing opposite marked end (Figure 27)

FIGURE 27



JOB SHEET #5

E. Place bender mark "B" on mark made in step B (See Figure 27)

F. Position tubing and bender on floor with one foot on the bender heel, keeping bender mark "B" on conduit mark

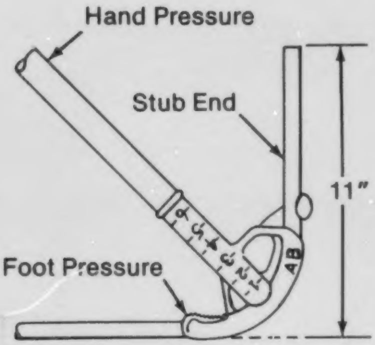
G. Place heavy foot pressure on bender kick pad

H. Make one sweeping movement of bender handle until tubing is perpendicular to floor

I. Before removing bender, measure height of tubing end above floor (Figure 28)

(NOTE: If bend is an exact 90 degrees, the end will be 11 inches above the floor.)

FIGURE 28



J. Remove bender

(NOTE: Show your work to the instructor for evaluation and comment.)

K. Use hacksaw to cut off bent end of tubing

L. Practice procedure by repeating steps A through K as many times as possible, using up the 10 feet of tubing

M. Clean work area; return equipment and materials to proper storage

ELECTRICAL RACEWAYS
UNIT III

JOB SHEET #6 — MAKE BACK-TO-BACK BENDS ON 1/2-INCH EMT

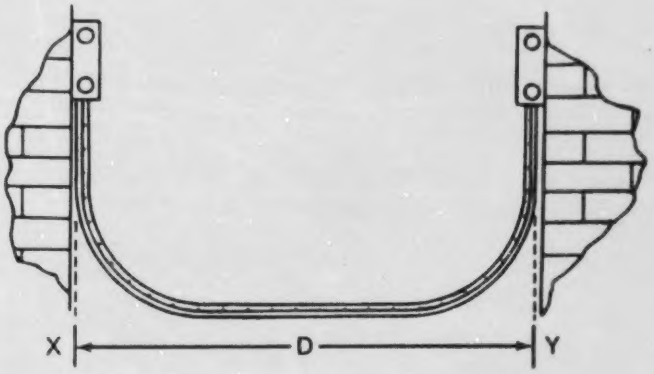
I. Equipment and materials

- A. 10 feet of 1/2-inch EMT
- B. Republic bender, Catalog #1472 or similar
- C. Hacksaw
- D. Measuring tape and marking pencil
- E. Eye protection

II. Procedure

- A. Measure 30 inches for distance D shown in Figure 29

FIGURE 29



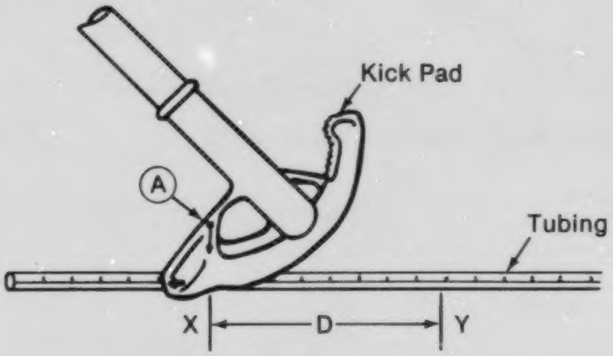
Used with permission of Republic Steel Corporation.

- B. Mark tubing at points X and Y (D distance) shown in Figure 28
- C. Put on eye protection

JOB SHEET #6

D. Place bender point "A" on tubing at point X as shown in Figure 30

FIGURE 30



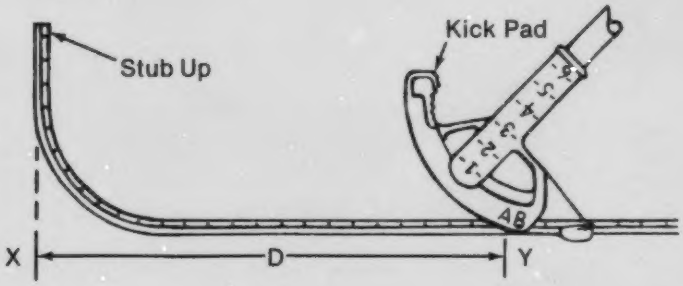
E. Place heavy foot pressure on bender kick pad

F. Make one sweeping movement with bender handle until tubing is perpendicular to floor

G. Remove bender

H. Place bender mark "A" on tubing at point Y in position to bend *toward* point X; make sure that stub-up (made in step E) points straight up (Figure 31)

FIGURE 31



Used with permission of Republic Steel Corporation.

JOB SHEET #6

I. Repeat steps E and F

J. Remove bender

K. Check distance from back to back

(NOTE: If bender point "A" did not slip and bends are truly 90 degrees, the measurement will be 30 inches, the distance of D.)

(NOTE: Show your work to the instructor for evaluation and comment.)

L. Use hacksaw to cut off bent end of tubing

M. Practice procedure by repeating steps A through L as many times as possible, using up the 10 feet of tubing

N. Clean work area; return equipment and materials to proper storage

ELECTRICAL RACEWAYS
UNIT III

JOB SHEET #7 — MAKE OFFSET BENDS ON ½-INCH EMT

I. Equipment and materials

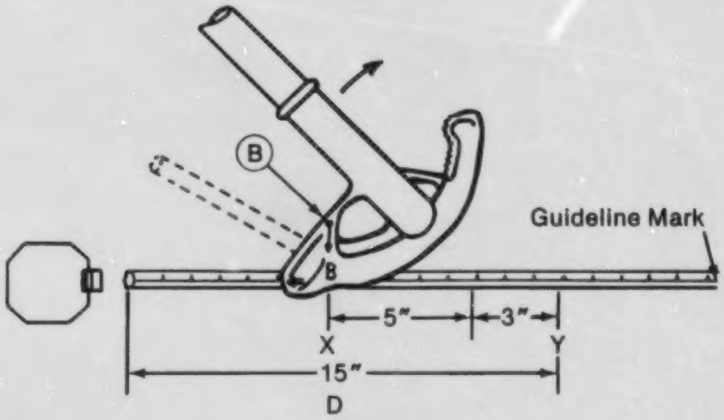
- A. ½-inch EMT bender
- B. 10 feet of ½-inch EMT
- C. Measuring tape and marking pencil
- D. Hacksaw
- E. Eye protection

II. Procedure

A. Measure 15 inches from end of tubing for distance D shown in Figure 32

(NOTE: This measurement represents the distance from outlet box to object to be passed.)

FIGURE 32



Used with permission of Republic Steel Corporation.

B. Mark the tubing at point Y shown in Figure 32

C. Measure back 8 inches from point Y, and mark tubing at this measurement to establish point X

(NOTE: The 8-inch number is determined by taking half the height of the offset and adding 5 inches.)

JOB SHEET #7

D. Put on eye protection

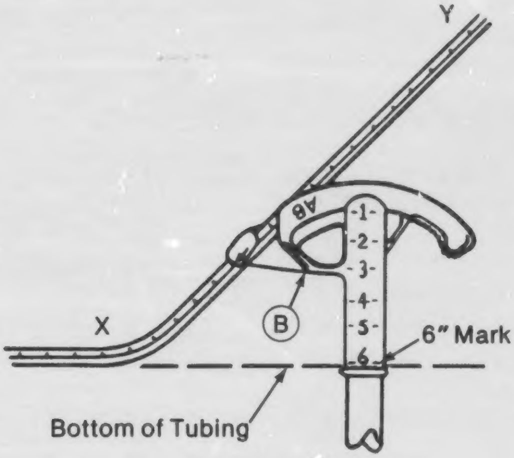
E. Place bender point "B" on tubing at point X, with bender in position to bend toward object to be passed

F. Make 45-degree bend

G. Remove bender

H. Reverse the tubing and slip the end of it through holding hook on bender so that the lower part of the 45-degree bend is in line with the 6-inch depth measurement on side of bender as shown in Figure 33; mark tubing at point B

FIGURE 33



Used with permission of Republic Steel Corporation.

I. Remove bender, and place on tubing with bender point "B" at 6-inch mark

J. Make 45-degree bend

K. Remove bender

(NOTE: This step completes the offset. Show work to instructor for evaluation and comments.)

L. Use hacksaw to cut off offset

M. Practice procedure at lest five times, making 1-inch, 2-inch, 3-inch, 4-inch, and 5-inch offsets

N. Clean work area; return equipment and materials to proper storage

ELECTRICAL RACEWAYS
UNIT III

JOB SHEET #8 — BEND A FOUR-POINT SADDLE ON ½-INCH EMT

I. Equipment and materials

  A. ½-inch EMT bender

  B. 10-foot piece of ½-inch EMT

  C. Measuring tape

  D. 2-by-4 beam to be saddled

  E. Eye protection

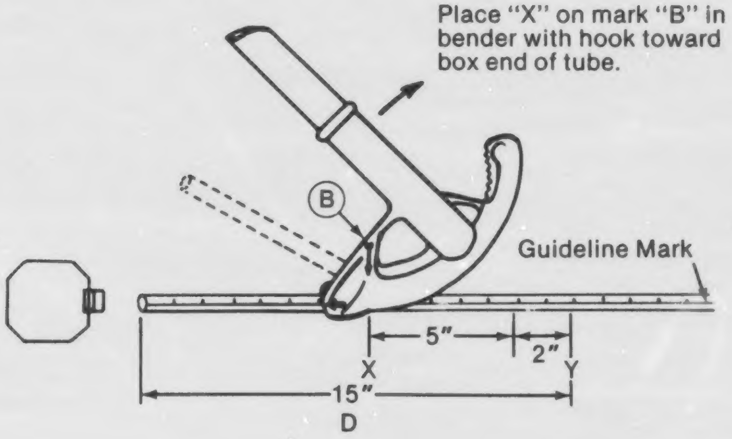
II. Procedure

  A. Put on eye protection

  B. Make a 4-inch offset bend (Figure 34)

  (NOTE: Half the height of offset [2 inches] plus 5 inches for ½-inch conduit equals 7-inch total.)

FIGURE 34



Place "X" on mark "B" in bender with hook toward box end of tube.

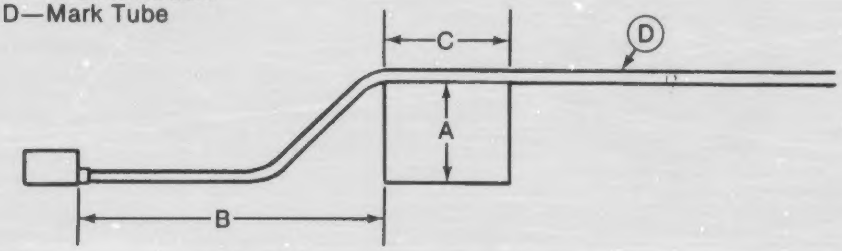
Used with permission of Republic Steel Corporation.

JOB SHEET #8

C. Lay offset across beam to be saddled, and mark tubing at point D shown in Figure 35

FIGURE 35

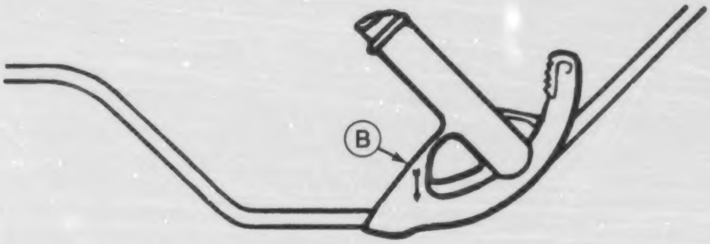
A—Height of Offset
B—Distance from Box to Offset
C—Width of Beam
D—Mark Tube



Used with permission of Republic Steel Corporation.

D. Place tubing in bender, with bender point "B" at mark D, and bender hook toward finished part of offset (Figure 36)

FIGURE 36



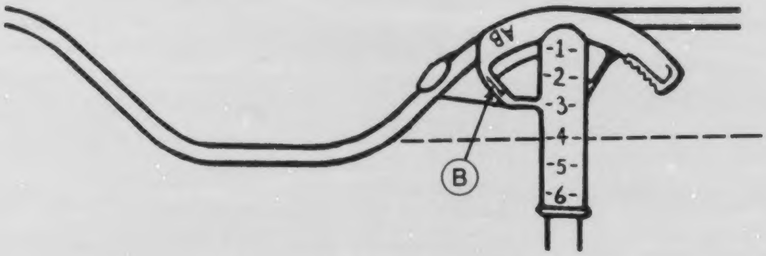
Used with permission of Republic Steel Corporation.

E. Make a 45-degree bend, and remove bender

JOB SHEET #8

F. Complete this leg of saddle by sighting along edge of tubing to the 4-inch mark on bender as shown in Figure 37; mark tubing at 4-inch mark

FIGURE 37



Used with permission of Republic Steel Corporation.

G. Remove bender, and place on tubing with bender point B at 4-inch mark

H. Make a 45-degree bend and remove bender

I. Place saddle over beam

(NOTE: Show work to instructor for evaluation and comments.)

J. Clean work area; return equipment and materials to proper storage

ELECTRICAL RACEWAYS
UNIT III

JOB SHEET #9 — BEND AND INSTALL 1/2-INCH EMT

I. Equipment and materials

(NOTE: Refer to *NEC,* Articles 300 and 110.)

A. Pouch tools

B. Eye protection

C. Hacksaw

D. 1/2-inch conduit bender

E. 20 feet of 1/2-inch EMT

F. Two 4-inch square outlet boxes with mounting screws

G. Space to install 20 feet of tubing with three 90-degree bends and a 4-inch square box at each end

H. Four 1/2-inch one-hole straps, or other supports

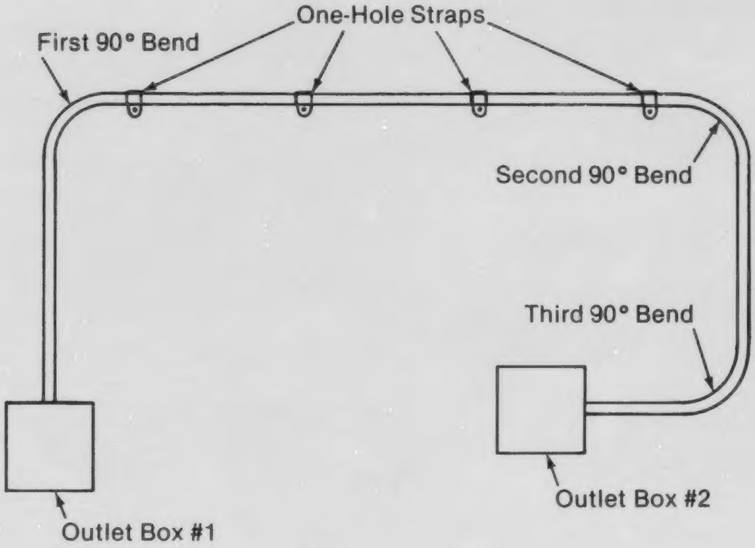
I. EMT couplings and connectors, setscrew or raintight

JOB SHEET #9

II. Procedure

A. Mount the two outlet boxes as shown in Figure 38

FIGURE 38


One-Hole Straps
First 90° Bend
Second 90° Bend
Third 90° Bend
Outlet Box #2
Outlet Box #1

B. Open knockout holes only where needed for tubing connectors

C. Install one EMT connector in each outlet box

D. Measure distance and tubing for first 90-degree bend shown in Figure 38

E. Make bend

F. Measure tubing for second 90-degree bend

G. Make bend

H. Install and fasten tubing as shown in Figure 38

I. Measure distance and tubing for third 90-degree bend

J. Bend tubing and install

(NOTE: If necessary, cut tubing to fit spacing. Be sure to wear eye protection when using hacksaw. Show work to instructor for evaluation and comments.)

K. Clean work area; return equipment and materials to proper storage

ELECTRICAL RACEWAYS
UNIT III

JOB SHEET #10 — CUT, REAM, AND INSTALL COUPLING ON ½-INCH PVC

I. Equipment and materials

- A. 10 feet of ½-inch PVC
- B. Hacksaw
- C. Skinning knife or other reaming tool
- D. ½-inch PVC coupling
- E. PVC cement
- F. Eye protection
- G. Measuring tape and marking pencil

II. Procedure

- A. Measure and mark a 3-inch segment of PVC
- B. Cut off 3-inch piece, using hacksaw

  (NOTE: PVC is soft enough to cut with a wood handsaw without damaging the saw.)

- C. Using knife or reaming tool, remove burrs from inside and outside of cut conduit

  (NOTE: Cleaner must be used if conduit has dirt or oil on it.)

- D. Install PVC coupling on cleaned piece of PVC
  1. Apply PVC cement to conduit *only*

     (NOTE: Close PVC cement container immediately after use. When PVC cement is applied to the female end of a splice, the cement is forced back into the conduit interior. When hard, it can damage insulation on wire and make pulling much more difficult.)

  2. Quickly insert conduit into coupling; twist the coupling one-quarter to one-half turn; let set for sixty seconds

  (NOTE: Show work to instructor for evaluation and comments.)

- E. Clean work area; return equipment and materials to proper storage

ELECTRICAL RACEWAYS
UNIT III

TEST

NAME ______________________________ SCORE ____________

1. Define *raceway.*

____

____

____

2. Name four types of electrical raceways in common use.

    a. ____

    b. ____

    c. ____

    d. ____

3. State uses and three fittings for rigid metal conduit and intermediate metal conduit.

    a. Typical uses — ______________________________

    b. Standard fittings

        1) ____

        2) ____

        3) ____

4. State uses and three fittings for electrical metallic tubing (EMT).

    a. Typical uses

        1) ____

        2) ____

        3) ____

        4) ____

TEST

b. Standard fittings

1) ______________________________

2) ______________________________

3) ______________________________

5. State three uses and three fittings for rigid nonmetallic conduit (PVC).

a. Typical uses

1) ______________________________

2) ______________________________

3) ______________________________

b. Standard fittings

1) ______________________________

2) ______________________________

3) ______________________________

6. State uses and fittings for flexible metal conduit.

a. Typical uses

1) ______________________________

2) ______________________________

b. Standard fittings

1) ______________________________

2) ______________________________

3) ______________________________

7. State uses and fittings for liquidtight flexible conduit.

a. Typical uses

1) ______________________________

____

2) ______________________________

____

TEST

b. Standard fittings

1) ______________________________

2) ______________________________

3) ______________________________

8. State uses and fittings for surface raceways (Wire Mold).

a. Typical uses

1) ______________________________

2) ______________________________

b. Standard fittings

1) ______________________________

2) ______________________________

3) ______________________________

9. State uses and three fittings for busways.

a. Typical uses

1) ______________________________

2) ______________________________

3) ______________________________

b. Standard fittings

1) ______________________________

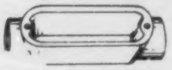
2) ______________________________

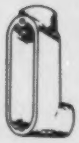
3) ______________________________

TEST

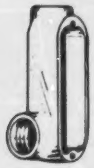
10. Identify conduit bodies commonly used in industry. Write the correct names in the blanks.

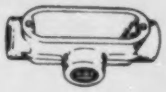
LL condulet	**C-condulet**
LR condulet	**T-condulet**
LB condulet	



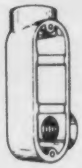


a. ______________________________ b. ______________________________





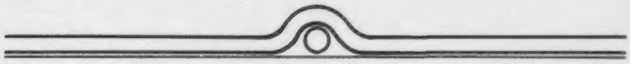
c. ______________________________ d. ______________________________



e. ______________________________

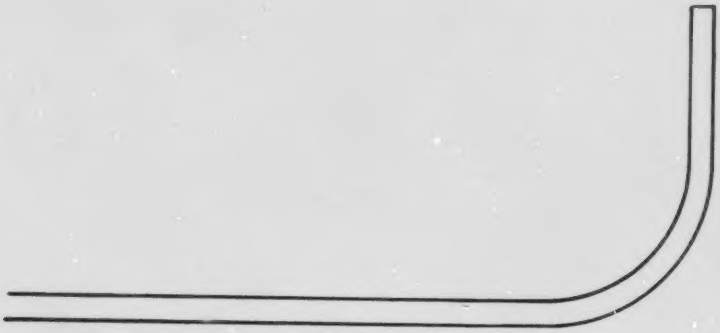
11. Identify types of conduit bends. Write the correct names in the blanks.

90-degree stub-up	**Four-point saddle**
90-degree back-to-back	**Three-point saddle**
Offset	

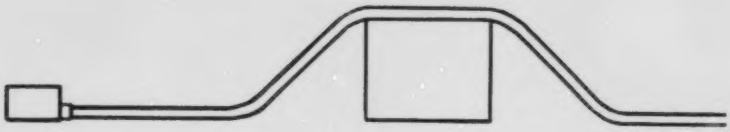


a. ____

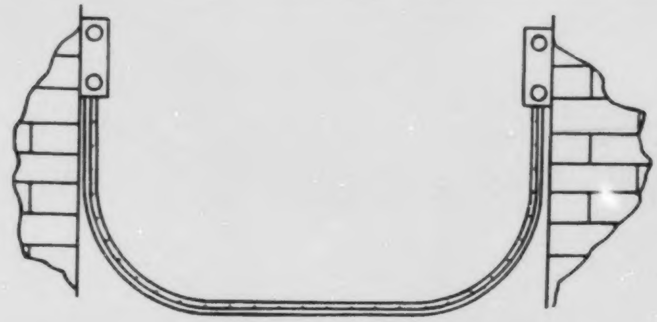
TEST



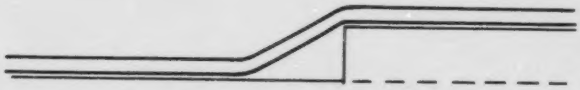
b. ____________________



c. ____________________



d. ____________________

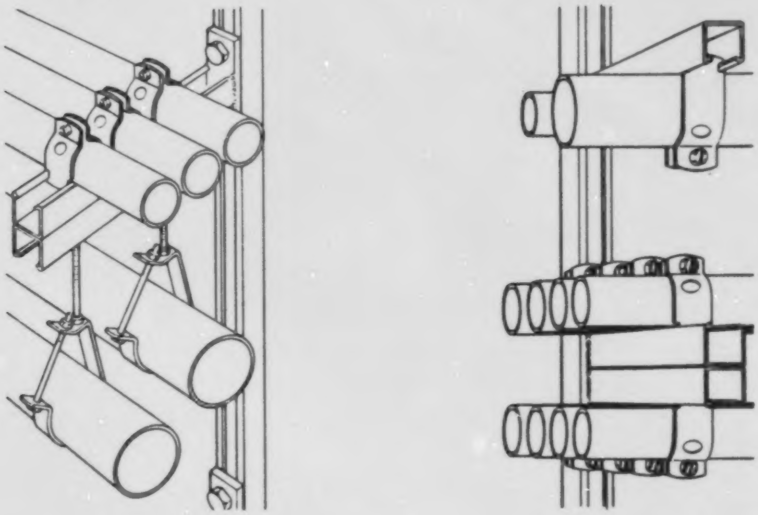


e. ____________________

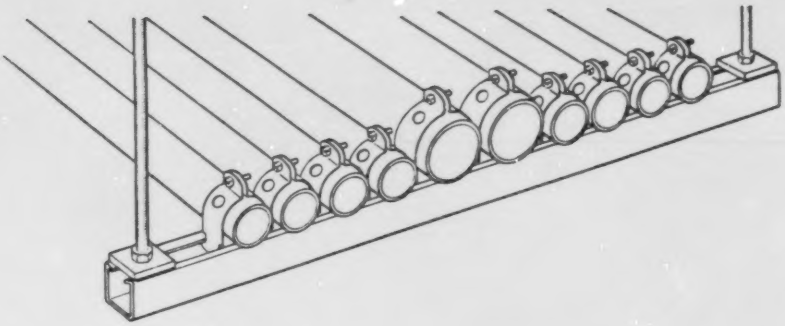
TEST

12. Identify conduit support methods. Write the correct names in the blanks.

One- or two-hole straps
Wall support brackets
Beam clamps and hanger rod supports
Conduit supports
T-bar support clips
Frame assembly
Tie wires or clamps for installation in concrete work

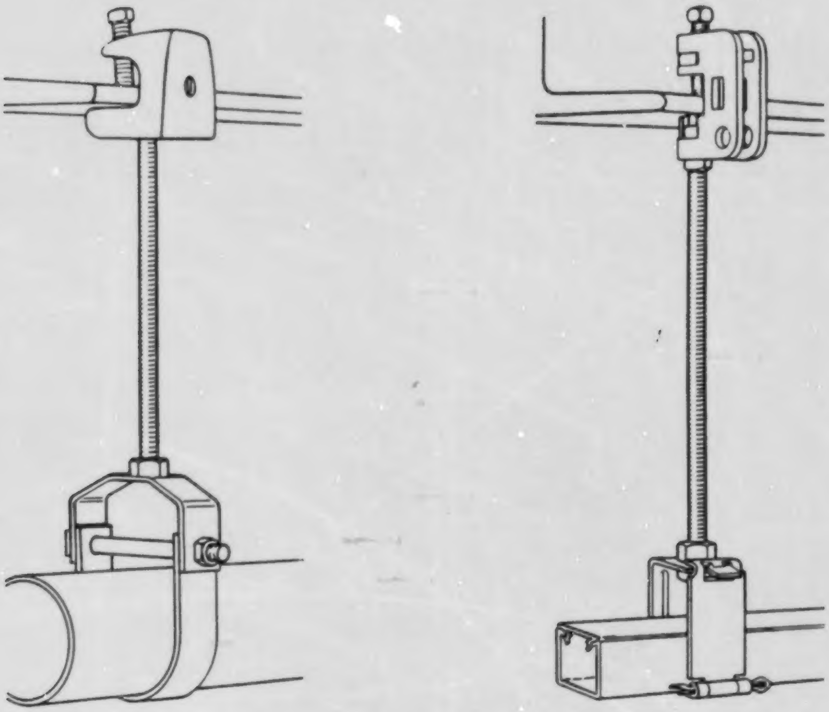


a. ____

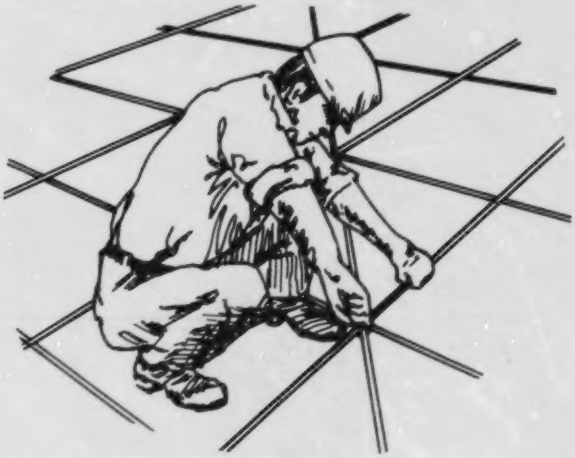


b. ____

TEST

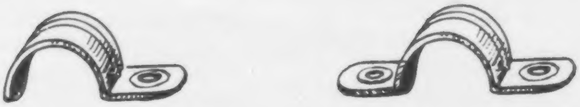


c. ______________________________

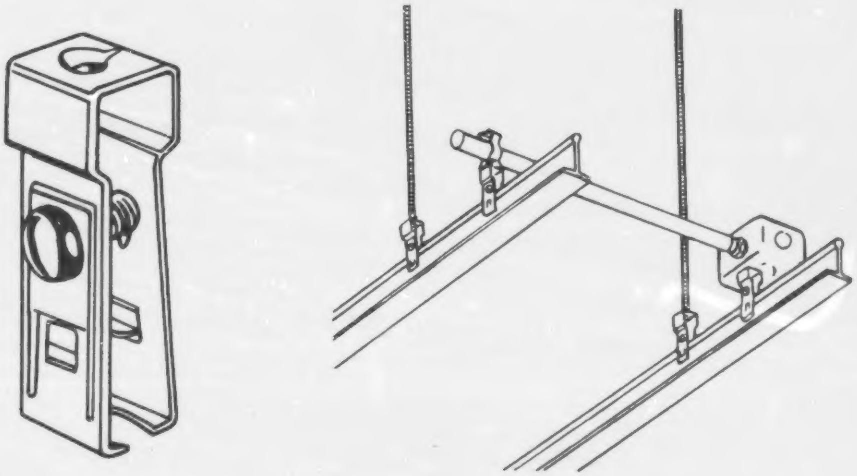


d. ______________________________

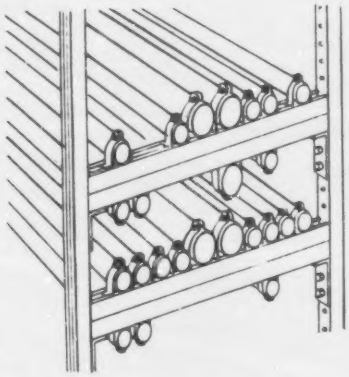
TEST



e. ____________________



f. ____________________



g. ____________________

TEST

(NOTE: Test question 13 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

13. Demonstrate the ability to

    a. Bend, cut, ream, and thread $^1/_2$-inch rigid metal conduit.

    b. Install setscrew fittings on $^1/_2$-inch EMT.

    c. Cut and ream EMT.

    d. Install a compression fitting on a piece of EMT.

    e. Bend EMT stub-ups.

    f. Make back-to-back bends on $^1/_2$-inch EMT.

    g. Make offset bends on $^1/_2$-inch EMT.

    h. Bend a four-point saddle on $^1/_2$-inch EMT.

    i. Bend and install $^1/_2$-inch EMT.

    j. Cut, ream, and install coupling on $^1/_2$-inch PVC.

ELECTRICAL RACEWAYS
UNIT III

ANSWERS TO TEST

1. Raceway — An enclosed channel designed expressly for holding wires, cables, or busbars, with additional functions as permitted by the *National Electrical Code*

2. Answer should include any four of the following

    a. Rigid metal conduit and intermediate metal conduit

    b. Electrical metallic tubing (EMT)

    c. Rigid nonmetallic conduit (PVC)

    d. Flexible metal conduit

    e. Liquidtight flexible metallic conduit

    f. Surface raceways (Wire Mold)

    g. Busways

3. a. Typical uses — In all locations and all atmospheric conditions

    b. Answer should include any three of the following standard fittings

        1) Threaded couplings

        2) Locknuts

        3) Threadless couplings

        4) Threadless connectors

        5) Bushings

        6) Factory elbows

4. a. Typical uses

        1) For exposed work

        2) For concealed work

        3) In wet locations

        4) In dry locations

ANSWERS TO TEST

b. Answer should include any three of the following standard fittings

   1) Setscrew connectors
   2) Setscrew couplings
   3) Compression connectors
   4) Compression couplings
   5) Locknuts
   6) Bushings

5. Answer should include any three of the following uses and fittings

   a. Typical uses

      1) For concealed work in walls, floors, and ceilings
      2) In corrosive conditions
      3) In cinder fill
      4) In wet locations
      5) For exposed locations not subject to physical damage
      6) For underground locations

   b. Standard fittings

      1) Couplings
      2) Male connectors
      3) Female connectors
      4) Factory elbows
      5) Locknuts

6. a. Typical uses

      1) For connecting commercial and industrial lighting fixtures
      2) For raceways between motors and motor controllers

ANSWERS TO TEST

b. Standard fittings

    1) Straight connectors
    2) 90-degree connectors
    3) Flex-to-pipe adapters

7. a. Typical uses

    1) In locations where conditions require flexibility and protection from liquids, vapors, or solids
    2) In certain hazardous locations

   b. Standard fittings

    1) Straight connectors
    2) 90-degree connectors
    3) Pipe adapters

8. a. Typical uses

    1) On surface of finished walls
    2) Only inside for NEMA 1 conditions

   b. Standard fittings

    1) Elbows
    2) Box adapters
    3) Conduit adapters

9. a. Typical uses

    1) In industrial plants
    2) For power distribution
    3) In assembly lines

ANSWERS TO TEST

- b. Answer should include any three of the following standard fittings
    1) Plug-in busways
    2) Switch adapters
    3) Tees
    4) End caps
    5) Elbows

10. a. C-condulet
    - b. LB condulet
    - c. LL condulet
    - d. T-condulet
    - e. LR condulet

11. a. Three-point saddle
    - b. 90-degree stub-up
    - c. Four-point saddle
    - d. 90-degree back-to-back
    - e. Offset

12. a. Wall support brackets
    - b. Conduit supports
    - c. Beam clamps and hanger rod supports
    - d. Tie wires or clamps for installations in concrete work
    - e. One- or two-hole straps
    - f. T-bar support clips
    - g. Frame assembly

13. Performance skills evaluated to the satisfaction of the instructor

BOXES AND ENCLOSURES
UNIT IV

UNIT OBJECTIVE

After completing this unit, the student should be able to identify and install electrical boxes and enclosures used in industrial electrical installations. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with boxes and enclosures.
2. Identify classes of outlet boxes used in industrial wiring.
3. List information needed to calculate boxfill.
4. Match types of enclosures to their correct conditions for use.
5. State purposes of controller enclosures.
6. Label types of devices commonly used in industrial wiring.
7. Label types of covers and plates used in electrical wiring.
8. Identify supports and anchors commonly used in industrial wiring.
9. Identify screws, bolts, and nuts commonly used in industrial wiring.
10. Identify classes of box-mounting devices for steel structures.
11. Determine correct number of conductors for boxfill.
12. Demonstrate the ability to
    a. Install outlet boxes on wood studs on a framed wall.
    b. Install outlet boxes on steel studs and rods, using Caddy clips.
    c. Install outlet boxes on steel studs, using Caddy metal stud clips for switch boxes.
    d. Install masonry boxes in a block wall.

BOXES AND ENCLOSURES
UNIT IV

SUGGESTED ACTIVITIES

I. Suggested activities

A. Make mock-ups for student practice.

1. Set up wood-frame wall sections so that students may complete Job Sheet #1.

2. Set up section of steel-stud wall so that students may complete Job Sheets #2 and #3.

3. Arrange for the masonry class to build a masonry wall section so that students may complete Job Sheet #4.

B. Order current Raco catalog from your local electrical supply house.

C. Arrange a field trip to a grain elevator, a fertilizer plant, an oil refinery, or other installation in which explosionproof or corrosionproof equipment has been installed.

D. Arrange for a field trip to one or more industrial construction sites so that students may observe installation of boxes and conduit.

(NOTE: Give demonstration or ask an on-site electrician to give a demonstration to the class on the proper procedure for removing knockouts from boxes and enclosures.)

E. Make transparencies.

F. Provide students with objective sheet.

G. Discuss unit and specific objectives.

H. Provide students with information, assignment, and job sheets.

I. Discuss information, assignment, and job sheets.

1. Discuss terms and definitions, using Information Sheet, Section I. Remind students that the various enclosures also have NEMA designations, i.e., a raintight enclosure is also known as a NEMA 3. Show the students several samples of boxes and enclosures so that they may compare and contrast.

2. Discuss box design features and classes of outlet boxes used in industrial wiring, using Information Sheet, Section II, and Transparencies #1 and #2. Remind students that outlet boxes are designed for a specific purpose and that there are hundreds of types of boxes. Careful consideration should be given to which type of box is needed for a specific job.

SUGGESTED ACTIVITIES

3. Discuss information needed to calculate boxfill, using Information Sheet, Section III, and Assignment Sheet #1. A thorough discussion of the many factors that affect boxfill should be covered. Stress that correct boxfill not only ensures safety, but also eases installation.

4. Discuss types of enclosures and conditions for their use, using Information Sheet, Section IV. Remind students that each enclosure is designed for a specific use, and that these uses must be strictly adhered to according to the *National Electrical Code.*

5. Discuss the purposes of controller enclosures, using Information Sheet, Section V. If possible, a tour of a local industrial plant whose atmosphere normally includes dust and other latent particles is recommended to show the amount of dust buildup possible within any controller box.

6. Discuss the types of devices commonly used in industrial wiring, using Information Sheet, Section VI. Tell students that there are devices other than those given in the information sheet, but that those listed in this unit constitute the most commonly used devices.

7. Discuss covers and plates used in electrical wiring, using Information Sheet, Section VII. Remind students that the *National Electrical Code* requires all boxes to be covered and sealed.

8. Discuss supports and anchors commonly used in industrial wiring, using Information Sheet, Section VIII and actual samples of such devices. Stress that the *National Electrical Code* specifies that all work must be mechanically secure and electrically safe. In order to be electrically safe, all boxes, conduit, hangers, fittings, and enclosures must be mechanically secure.

9. Discuss screws, nuts, and bolts commonly used in industrial wiring, using Information Sheet, Section IX. Remind students that mechanical soundness is the key purpose of each of the fastening devices.

10. Discuss classes and specific mounting devices for steel structures, using Information Sheet, Section X. Point out that sometimes a device is not adequate to give total support and that additional strapping or securing devices may be necessary.

J. Give test.

II. Instructional materials

A. Objective sheet

B. Suggested activities

SUGGESTED ACTIVITIES

C. Information sheet

D. Transparency masters

  1. TM #1 — Box Design Features

  2. TM #2 — Box Design Features (Continued)

E. Assignment Sheet #1 — Determine Correct Number of Conductors for Box-fill

F. Answers to assignment sheet

G. Job sheets

  1. Job Sheet #1 — Install Outlet Boxes on Wood Studs on a Framed Wall

  2. Job Sheet #2 — Install Outlet Boxes on Steel Studs and Rods, Using Caddy Clips

  3. Job Sheet #3 — Install Outlet Boxes on Steel Studs, Using Caddy Metal Stud Clips for Switch Boxes

  4. Job Sheet #4 — Install Masonry Boxes in a Block Wall

H. Test

I. Answers to test

III. Unit references

A. *Caddy Fasteners for the Construction Industry,* Catalog #150MPP9-81. Cleveland, Ohio: Erico Products, Inc., 1981.

B. National Fire Protection Association. *National Electrical Code 1984.* Quincy, Massachusetts: National Fire Protection Association, 1983.

C. Taylor, Mark. *Residential Wiring.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1978.

BOXES AND ENCLOSURES
UNIT IV

INFORMATION SHEET

I. Terms and definitions

- A. Outlet boxes — Electrical boxes designed for the mounting of receptacles, switches, light fixtures, or other devices
- B. Junction boxes — Enclosures designed for conduit or cable entrances to enclose the conductor splices and taps
- C. National Electrical Manufacturers Association (NEMA) — Organization responsible for setting specifications for various classes of enclosures
- D. NEMA enclosures — Electrical enclosures specifically designed to standards for use in specific locations and for various conditions such as indoor, outdoor, dusty, corrosive, wet, and explosive conditions
- E. Cabinet — Enclosure designed either for surface or flush mounting; provided with a frame, mat, or trim in which a swinging door or doors may be hung
- F. Disconnecting means — Device, group of devices, or other means by which circuit conductors can be disconnected from their source of supply
- G. Dustproof — So constructed or protected that dust will not interfere with successful operation
- H. Dusttight — So constructed that dust will not enter the enclosing case
- I. Rainproof — So constructed, protected, or treated as to prevent rain from interfering with successful operation
- J. Raintight — So constructed or protected that exposure to a beating rain will not result in the entrance of water
- K. Joint Industry Conference (JIC) boxes — Boxes or enclosures made to Joint Industry Conference standards for such uses as junction boxes and housing terminal blocks
- L. Explosionproof — Capable of containing hot explosive flames within the enclosure to prevent explosions in the surrounding atmosphere
- M. Knockout (KO) — Partially cut out piece of metal or plastic that can be forced out when a hole is needed
- N. Boxfill — Number of conductors of a certain size permitted in a box; number is based on cubic inches of box

INFORMATION SHEET

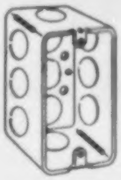
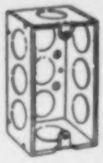
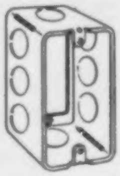
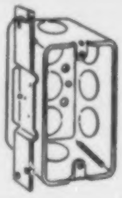
II. Classes of outlet boxes used in industrial wiring (Transparencies #1 and #2)

A. Outlet boxes (device boxes)

(NOTE: Most boxes can be purchased in metal or in a nonmetallic composition such as fiber, plastic, nylon, or rubber.)

1. Handy boxes (Figure 1)

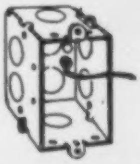
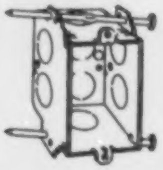
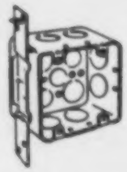
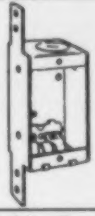
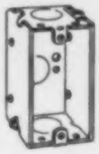
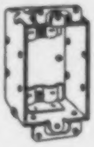
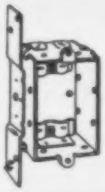
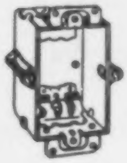
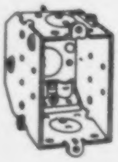
FIGURE 1

One-Piece Molded Construction	**One-Piece Welded Construction**	**Extension**	**Box with Bracket**
			

INFORMATION SHEET

2. Switch boxes (Figure 2)

FIGURE 2

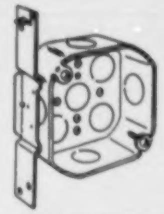
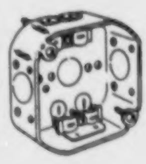
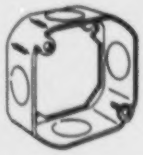
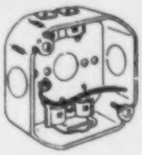
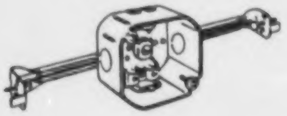
Gangable with Grounding Pigtail	Nail-On	Solid Two-Gang Bracket
		
Nongangable Bracket with Cable Clamps	**Gangable with Nail Holes**	**Gangable with Ears and Cable Clamps**
		
Gangable Bracket with Cable Clamps	**Box with Drywall Grips, Cable Clamps, and Ears**	**Beveled Corner with Clamps**
		

INFORMATION SHEET

B. Octagon boxes (Figure 3)

(NOTE: Octagon boxes, like switch boxes, can be either metallic or nonmetallic; like switch boxes, they can be purchased in many different depths.)

FIGURE 3

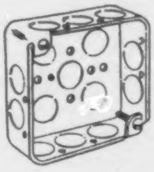
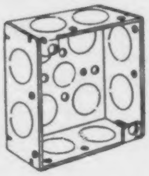
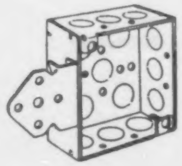
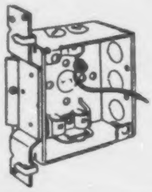
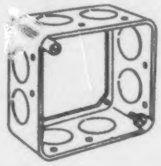
<table>
<tr><th colspan="2">Box with Bracket</th><th colspan="2">Box with Cable Clamps and Nail Holes</th><th colspan="2">Extension</th></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><th colspan="3">Box with Cable Clamps and Grounding Pigtail</th><th colspan="3">Box with Bar Hanger and Cable Clamps</th></tr>
<tr><td colspan="3"></td><td colspan="3"></td></tr>
</table>

INFORMATION SHEET

C. Square boxes (Figure 4)

(NOTE: Square boxes are usually used in conjunction with covers designed for special purposes.)

FIGURE 4

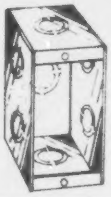
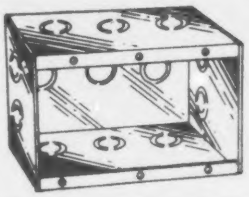
<table>
<tr><th colspan="2">One-Piece Molded Construction</th><th colspan="2">One-Piece Welded Construction</th><th colspan="2">Box with Bracket</th></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><th colspan="3">Box with Bracket, Cable Clamps, and Grounding Pigtail</th><th colspan="3">Extension</th></tr>
<tr><td colspan="3"></td><td colspan="3"></td></tr>
</table>

D. Masonry boxes (Figures 5 and 6)

(NOTE: Masonry boxes have square corners that are easier to cut and save installation time. The boxes are deep so that conduit will position in the voids.)

1. Regular masonry boxes

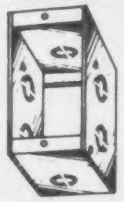
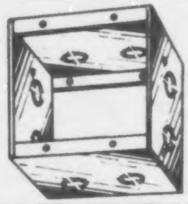
FIGURE 5

Single-Gang	Three-Gang
	

INFORMATION SHEET

2. Masonry through-the-wall boxes

FIGURE 6

Single-Gang	Two-Gang
	

III. Information needed to calculate boxfill (Assignment Sheet #1)

A. Cubic inches of box

(NOTE: Multiplying width times height times depth gives cubic inches.)

B. Size of wire

C. Number of devices and grounds

IV. Types of enclosures and their conditions for use

A. General duty — For normal use in locations without excessive dust, moisture, or corrosive atmospheres

B. Dustproof — For use where dust could interfere with normal operation

EXAMPLES: Feed mill, cement plant

C. Weatherproof — For use where rain or dust could interfere with normal operation

EXAMPLE: Irrigation motor controller

D. Watertight — For use in wet locations

EXAMPLES: Milk plant, mines

E. Corrosionproof — For use in locations having corrosive atmospheres

EXAMPLES: Galvanizing plant, fertilizer plant

INFORMATION SHEET

F. Explosionproof — For use in hazardous locations

EXAMPLES: Grain elevators, oil refineries, chemical plants

V. Purposes of controller enclosures

A. Keeping boxes and enclosures clean

(NOTE: Relays and contactors should be cleaned periodically to ensure continued operation.)

B. Keeping boxes and enclosures dry

(NOTE: Moisture is one of the greatest enemies of electrical insulation. Moisture due to condensation may collect inside a sealed enclosure. Heaters are often used to correct this condition.)

C. Protecting boxes and enclosures from accidental contact

(CAUTION: Never bring metal or other objects into contact with live parts.)

D. Preventing injuries

(CAUTION: To avoid personal injury, protective covers must be in place when system is in operation.)

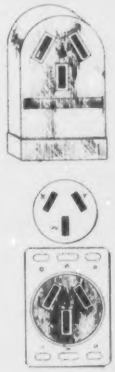
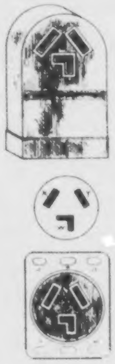
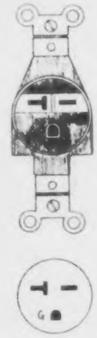
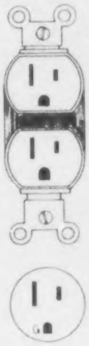
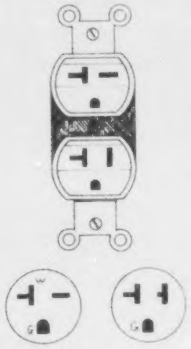
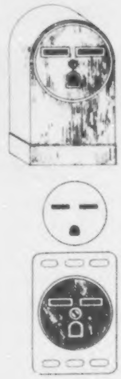
INFORMATION SHEET

VI. Types of devices commonly used in industrial wiring

(NOTE: Manufacturers make different grades of devices. Price and quality vary with the grades. Specification grade is the most expensive. Before installing devices, check the grade requested in the job bid.)

A. Receptacles (Figure 7)

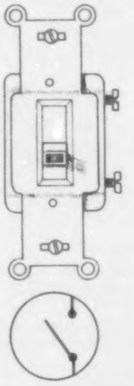
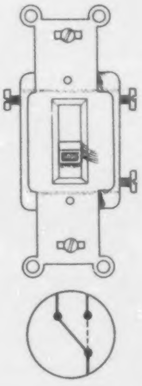
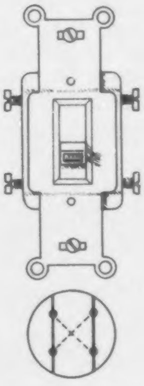
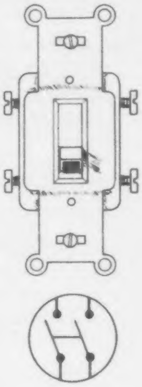
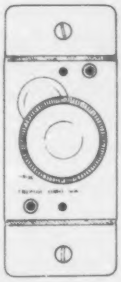
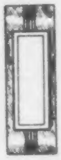
FIGURE 7

125/250 V, 50 A	125/250 V, 30 A	250 V, 20 A
		
Duplex Grounding **125 V, 15 A**	**Dual Voltage** **125/250 V, 20 A**	**250 V, 30 A**
		

INFORMATION SHEET

B. Switches (Figure 8)

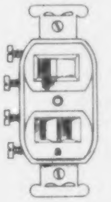
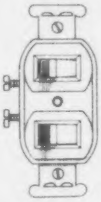
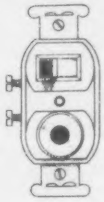
FIGURE 8

Single Pole	Three-Way	Four-Way
		
Double Pole	**Dimmer**	**Low-Voltage Push Button**
		

INFORMATION SHEET

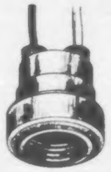
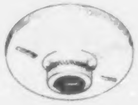
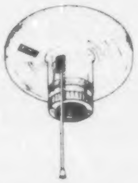
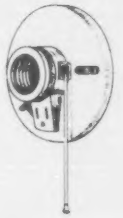
C. Combination devices (Figure 9)

FIGURE 9

Switch and Receptacle	Two Switches	Switch and Pilot Light
		

D. Sockets (Figure 10)

FIGURE 10

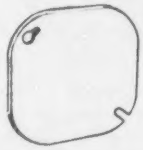
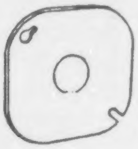
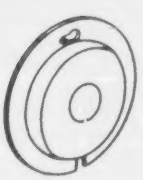
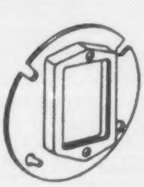
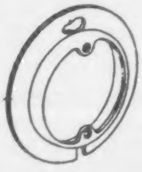
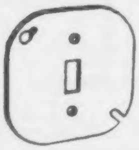
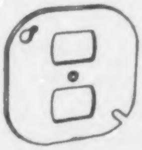
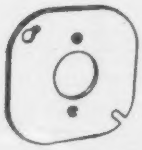
Keyless Pigtail	Keyless Cover
	
Pull-Chain Cover	**Pull-Chain Cover with Grounding-Type Receptacle**
	

INFORMATION SHEET

VII. Types of covers and plates used in electrical wiring

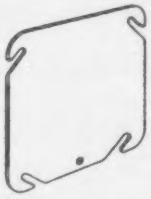
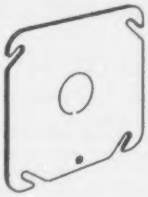
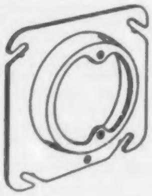
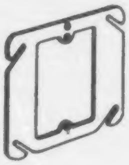
A. Round covers (Figure 11)

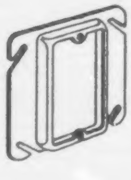
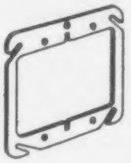
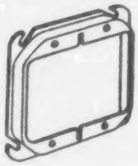
FIGURE 11

Flat Blank	**Flat Blank with Knockout**	**Raised with Knockout**	**Raised for Single Device**
			
Raised Open	**Flat Toggle**	**Flat Duplex Receptacle**	**Flat Single Receptacle**
			

B. Square covers (Figure 12)

FIGURE 12

Flat Blank	**Flat Blank with Knockout**	**Raised Open**	**Flat for Single Device**
			

Raised for Single Device	**Flat for Two Devices**	**Raised for Two Devices**
		

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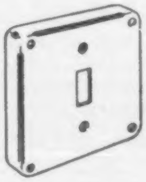
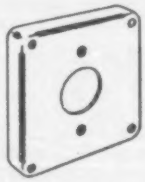
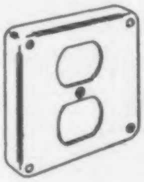
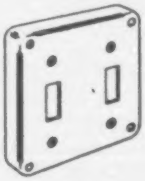
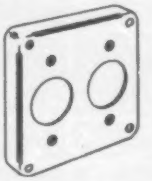
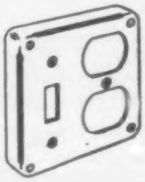
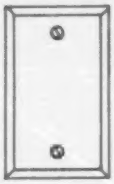
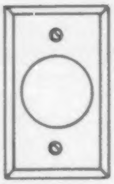
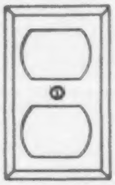
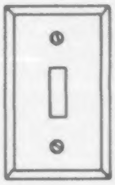
C. Exposed work raised square covers (Figure 13)

FIGURE 13

Single Toggle	Single Receptacle	Duplex Receptacle
		
Two-Toggle	**Two-Receptacle**	**Toggle and Duplex Receptacle**
		

D. Handy box covers (Figure 14)

FIGURE 14

Blank	Single Receptacle
	
Duplex Receptacle	**Single Toggle**
	

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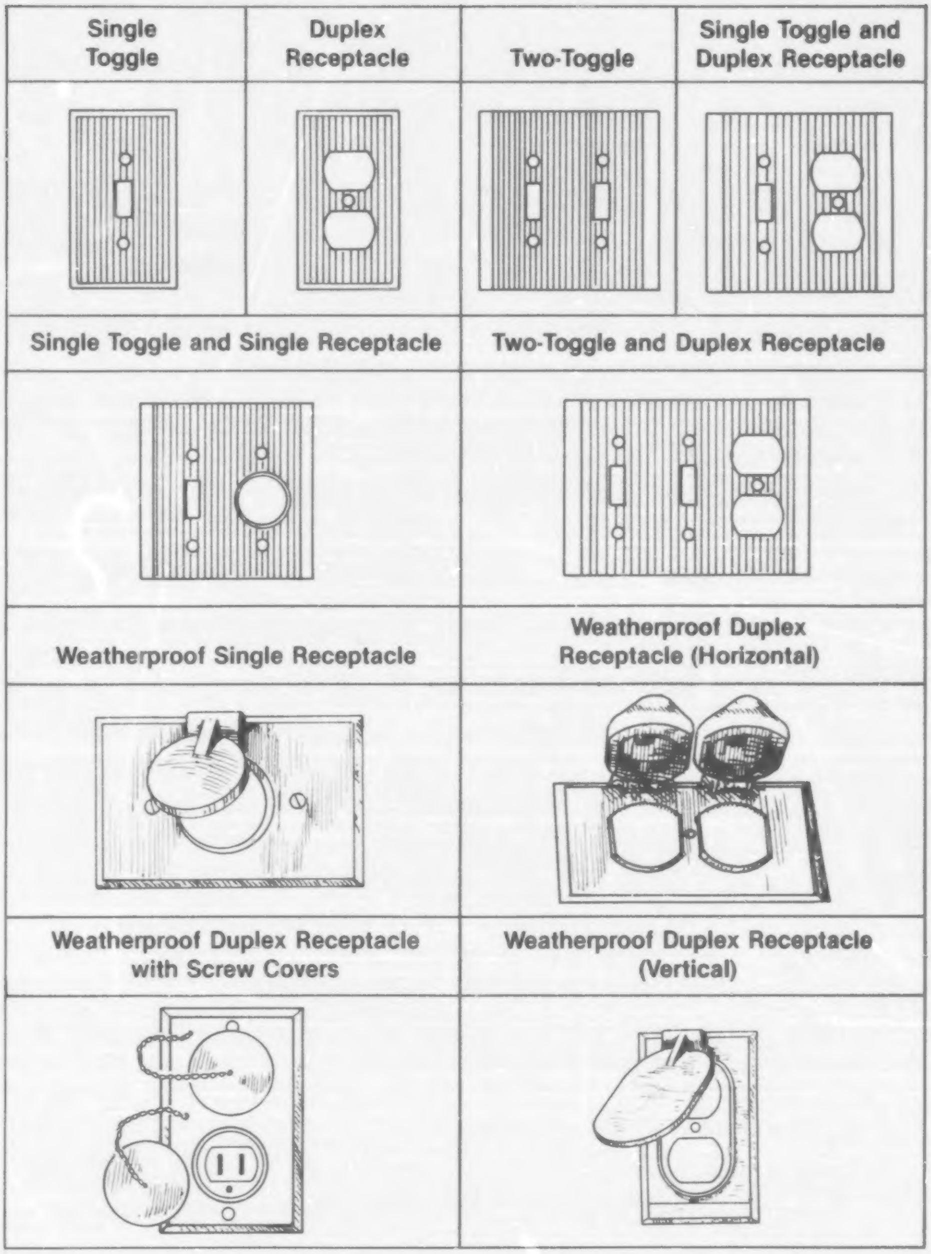
E. Wall plates (Figure 15)

FIGURE 15

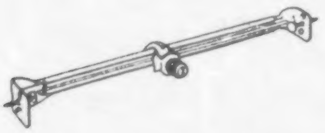

Single Toggle
Duplex Receptacle
Two-Toggle
Single Toggle and Duplex Receptacle
Single Toggle and Single Receptacle
Two-Toggle and Duplex Receptacle
Weatherproof Single Receptacle
Weatherproof Duplex Receptacle (Horizontal)
Weatherproof Duplex Receptacle with Screw Covers
Weatherproof Duplex Receptacle (Vertical)

INFORMATION SHEET

VIII. Supports and anchors commonly used in industrial wiring (Figures 16-24)

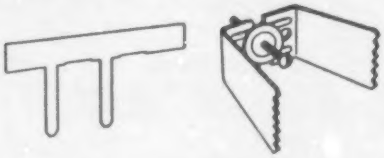
A. Bar hanger

FIGURE 16



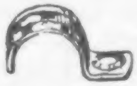
B. Switch-box supports

FIGURE 17



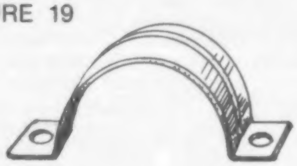
C. One-hole strap

FIGURE 18



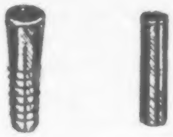
D. Two-hole strap

FIGURE 19



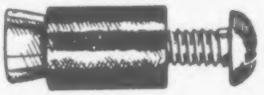
E. Plastic anchors

FIGURE 20



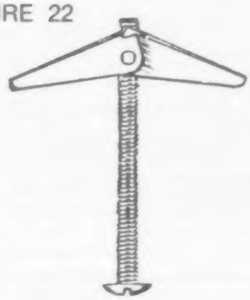
F. Lead anchor

FIGURE 21



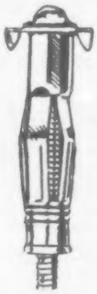
G. Toggle bolt

FIGURE 22



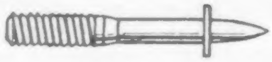
H. Molly bolt

FIGURE 23



I. Drive stud

FIGURE 24



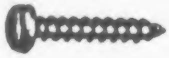
INFORMATION SHEET

IX. Screws, bolts, and nuts commonly used in industrial wiring (Figures 25-38)

A. Screws

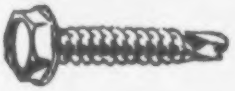
1. Sheet metal screw

FIGURE 25



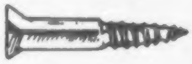
2. Self-drilling screw

FIGURE 26



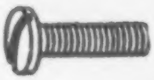
3. Wood screw

FIGURE 27



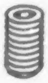
4. Machine screw

FIGURE 28



5. Setscrew

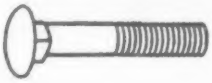
FIGURE 29



B. Bolts

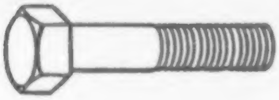
1. Carriage bolt

FIGURE 30



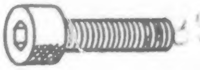
2. Hex-head bolt

FIGURE 31



3. Hex-socket-head bolt

FIGURE 32

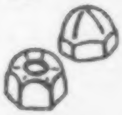


INFORMATION SHEET

C. Nuts

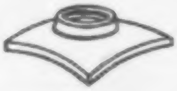
1. Acorn nut

FIGURE 33



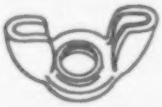
2. Spring nut

FIGURE 34



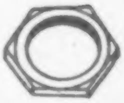
3. Wing nut

FIGURE 35



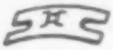
4. Fixture nut

FIGURE 36



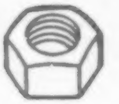
5. Single-thread nut

FIGURE 37



6. Plain hex nut

FIGURE 38



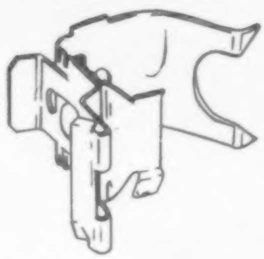
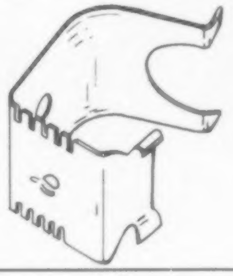
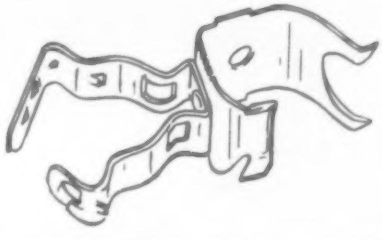
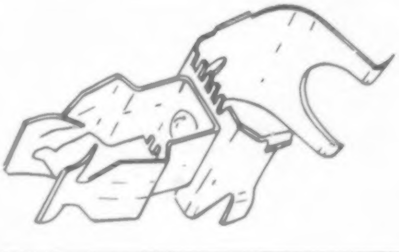
INFORMATION SHEET

X. Classes of box-mounting devices for steel structures

A. Metal stud clips for switch boxes (Figure 39)

(NOTE: Some types of metal stud supports may require extra screws to secure them to studs.)

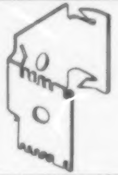
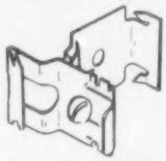
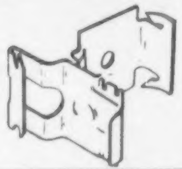
FIGURE 39

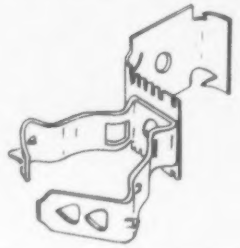
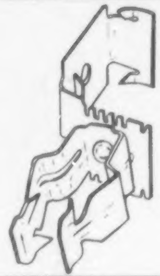
Riveted for Dry Wall, with Screw Adjustable 1/4" to 3/4"	**1/4"-20 Thread Impression to Metal Stud**
	
1/2" to 1" Conduit to Metal Stud	**1/2" to 1" Conduit to Metal Stud**
	

INFORMATION SHEET

B. MF clips for switch boxes (Figure 40)

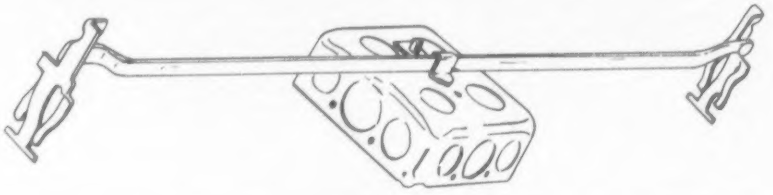
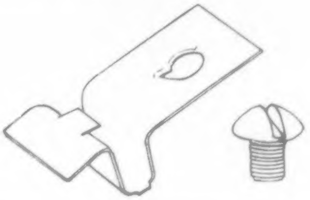
FIGURE 40

¼"-20 Thread Impression to Metal Stud	**With Screw Adjustable ¼" through ¾"**	**Riveted for Flush Wall or ¼" to ¾" Dry Wall**
		

Conduit on BX to Metal Stud	**½" to 1" Conduit to Metal Stud**
	

C. Acoustical tee-bar electrical box hanger and mounting clip (Figure 41)

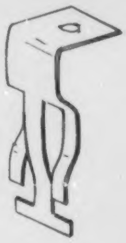
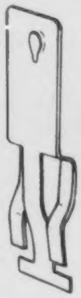
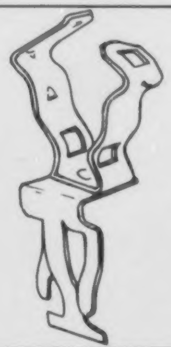
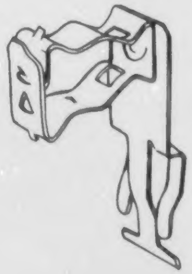
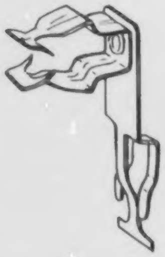
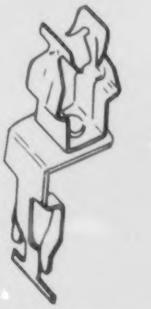
FIGURE 41

Acoustical "Tee-Bar" Electrical Box Hanger

Mounting Clip


INFORMATION SHEET

D. Acoustical tee-bar clips (Figure 42)

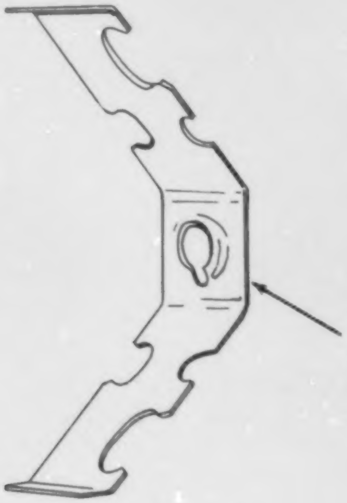
FIGURE 42

Top-Mount, with ¼"-20 Thread Impression	Side-Mount, with ¼"-20 Thread Impression	Top-Mounted Conduit Clip for ⅜" or ½" to ¾" Conduit
		
With Side-Mounted Conduit Clip for ⅜" or ½" to ¾" Conduit	**With Side-Mounted Conduit Clip for ½", ¾" or 1" Conduit**	**With Top-Mounted Conduit Clip for ½" or ¾" Conduit**
		

INFORMATION SHEET

E. Conduit box clip (Figure 43)

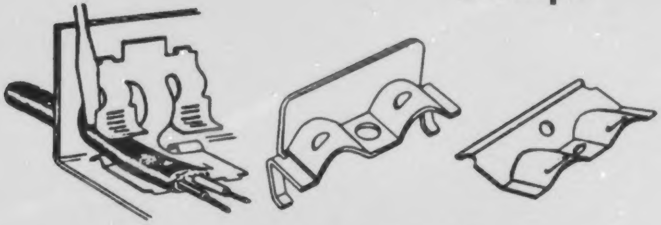
FIGURE 43



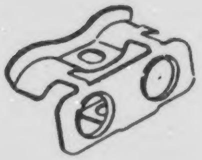
¼"-20 Thread Impression

Box Design Features

Clamps

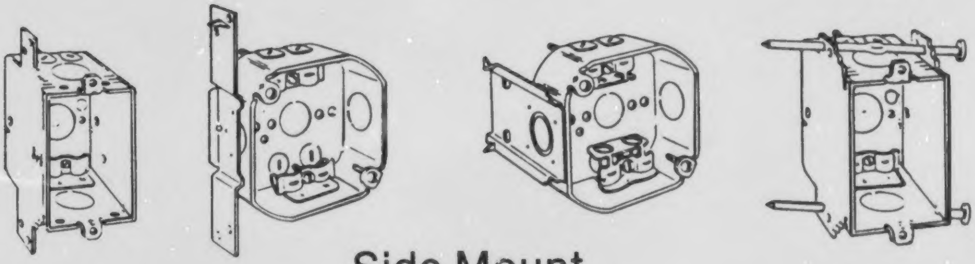


Nonmetallic
Cable Clamps

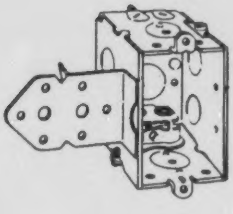


Metallic
Cable Clamp

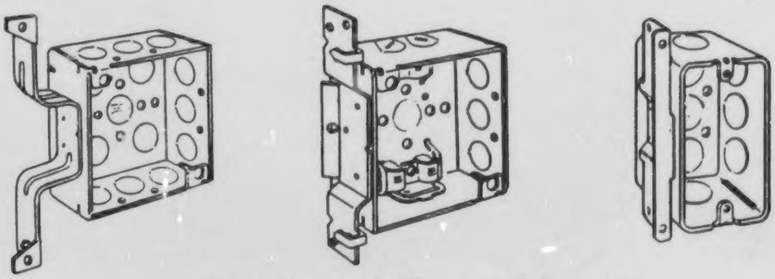
Brackets



Side Mount



Front
Mount



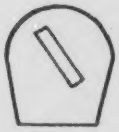
Side and Front Mount

Box Design Features

(Continued)

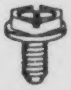
Box Openings

Knockout

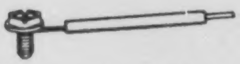


Pry-Out

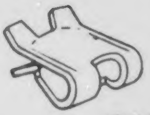
Grounding Equipment



Screw

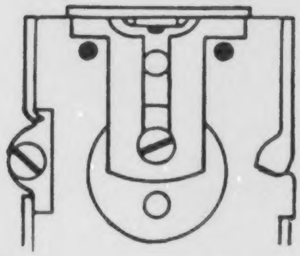


Screw with Pigtail

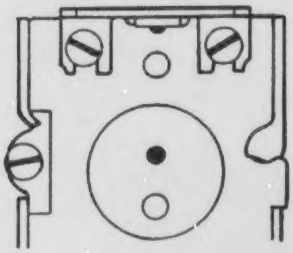


Clip

Plaster Ears



One-Screw Design



Two-Screw Design

BOXES AND ENCLOSURES
UNIT IV

ASSIGNMENT SHEET #1 — DETERMINE THE CORRECT NUMBER OF CONDUCTORS FOR BOXFILL

NAME ______________________________ SCORE ________________

The industrial electrician must be able to choose a box of correct size and then determine the number of conductors permitted according to the *National Electrical Code*, Article 370-6.

To find boxfill, subtract one conductor per device and one conductor per one or more grounds from the maximum allowed number of conductors.

EXAMPLE: 4" × 2 1/8" box, two devices, #12 wire

1. Referring to box dimensions and wire size, locate the maximum number of conductors on chart in Article 370-6 (maximum number = 13).
2. Subtract one conductor for each device (13 − 2 = 11).
3. Subtract one conductor for ground (11 − 1 = 10).
4. Answer equals boxfill (boxfill = 10 conductors).

A. 4" × 2 1/8", no device, round box, #12 wire

Boxfill = ____________________ conductors

B. 3 3/4" × 2" × 3 1/2", one device, masonry box, #12 wire

Boxfill = ____________________ conductors

C. 3" × 2" × 1 1/2", one device, #10 wire

Boxfill = ____________________ conductors

ASSIGNMENT SHEET #1

D. 4" x 2 1/8" x 1 7/8", one device, #10 wire

Boxfill = ______________________ conductors

E. 4 11/16" x 1 1/2", two device, square box, #12 wire

Boxfill = ______________________ conductors

F. 4" x 1 1/4", round box, #12 wire

Boxfill = ______________________ conductors

G. 3" x 2" x 2 1/2", no device, #10 wire

Boxfill = ______________________ conductors

H. 3" x 2" x 3 1/2", no device, #10 wire

Boxfill = ______________________ conductors

ASSIGNMENT SHEET #1

I. 4" × 2 1/8" × 1 1/2", no device, #12 wire

Boxfill = ______________________ conductors

J. 4" × 1 1/4", two devices, square box, #12 wire

Boxfill = ______________________ conductors

BOXES AND ENCLOSURES
UNIT IV

ANSWERS TO ASSIGNMENT SHEET

Assignment Sheet #1

A. 8

B. 7

C. 1

D. 3

E. 10

F. 4

G. 4

H. 6

I. 3

J. 5

BOXES AND ENCLOSURES
UNIT IV

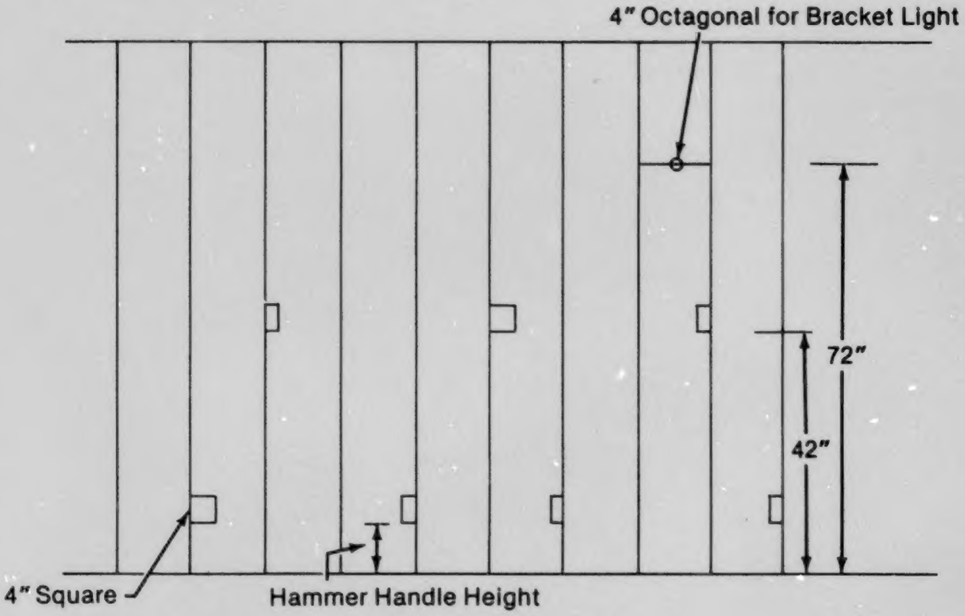
JOB SHEET #1 — INSTALL OUTLET BOXES ON WOOD STUDS ON A FRAMED WALL

I. Equipment and materials

A. Pouch tools, including hammer and tape

B. Construction blueprint showing locations and other necessary information for box installation (Figure 44)

FIGURE 44



C. 8-foot section of framed wall with 2" × 4" studs

D. Five outlet boxes, Raco #560 or equivalent

E. Two 4-inch square boxes, Raco #255 or equivalent

F. One plaster ring, Raco #772 or equivalent

G. One plaster ring, Raco #778 or equivalent

H. #8 mounting nails

I. 4-inch octagon box, Raco #125 or equivalent

J. One expandable hanger bar, Raco #924 or equivalent

JOB SHEET #1

II. Procedure

A. View blueprint for installation information to determine location of boxes

(NOTE: Mount boxes to allow for 5/8-inch Sheetrock.)

B. Lay out job by marking studs where boxes are to be installed

C. Place boxes on floor along wall where each is to be installed

D. Measure heights, and mark studs for mounting boxes

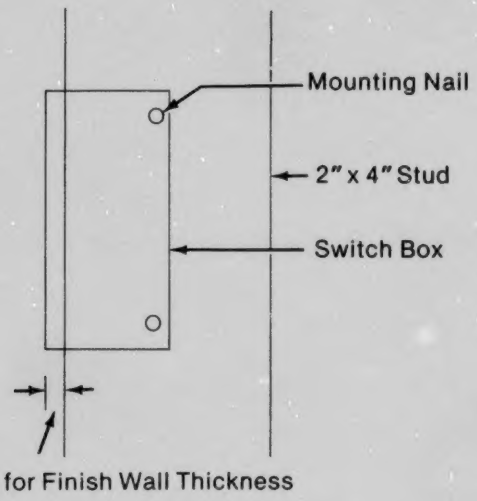
(NOTE: A quick accurate method for measuring for box installation is to cut a piece of conduit, lathe, or other similar material to proper length from floor or floor plate to bottom of box. Boxes can be held on top of the measuring device and fastened to stud. This will prevent reading a rule for locating each box. A method often used in industry for height location of receptacle boxes is to set a hammer on the floor and position the box on top of the handle. The receptacle box can be fastened to the stud at that height.)

E. Mount outlet boxes (Figure 45)

1. Mount electrical boxes to studs at the locations and heights marked, with front edge of boxes parallel to face of stud and extended 1/2 inch to allow for 5/8-inch Sheetrock (See Figure 44)

(NOTE: Four-inch square boxes are usually mounted with #8 or roofing nails, and switch boxes are usually mounted with #16 nails.)

FIGURE 45 — Switch box mounted on a 2-inch by 4-inch wall stud



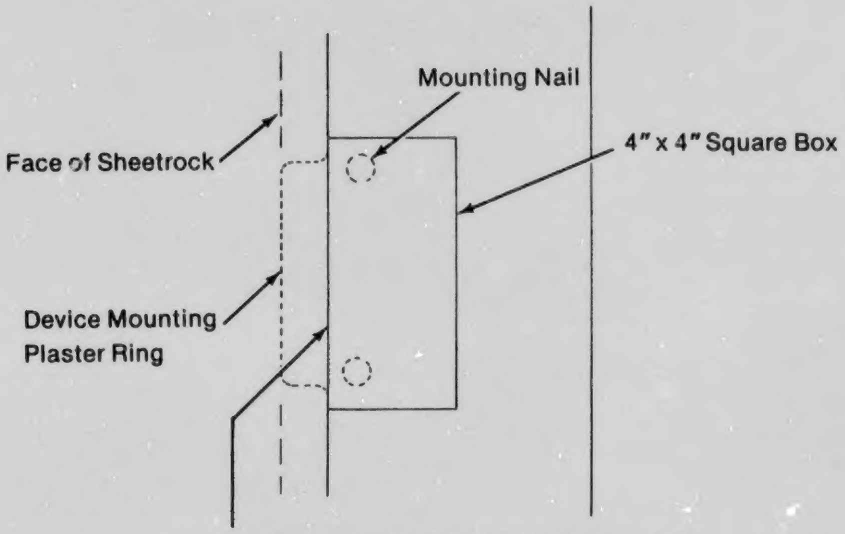
JOB SHEET #1

F. Mount 4-inch square boxes to studs at the height and location as marked with front edge of box flush with face of stud (Figure 46)

(NOTE: Set four-inch square boxes 1/2 inch lower than switch boxes, device screws inside.)

FIGURE 46

4" x 4" Box Mounted on
2" x 4" Stud


Mounting Nail
Face of Sheetrock
4" x 4" Square Box
Device Mounting
Plaster Ring

Front of box should be flush with 2" x 4" stud.

JOB SHEET #1

G. Install octagonal outlet box for wall bracket light between two studs at location and height marked

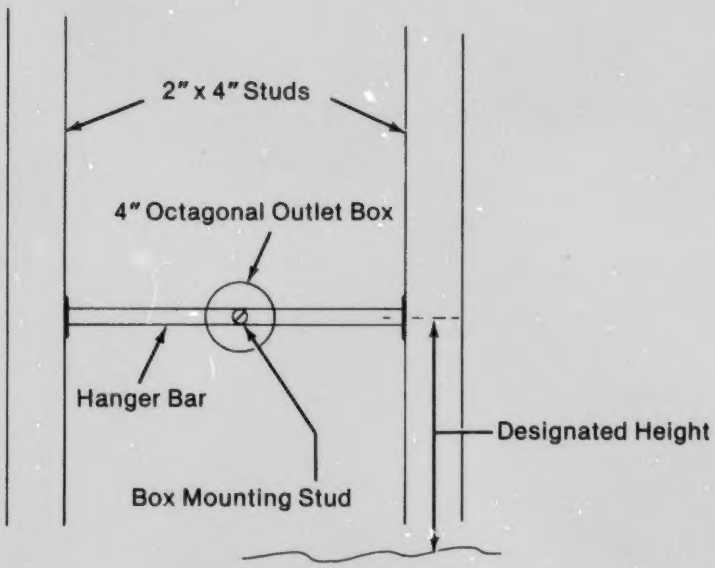
1. Spread expandable hanger bar to proper length to properly fit between studs

2. Attach hanger bar to studs (Figure 47)

   (NOTE: Hanger bars are usually fastened to studs with #8 nails.)

FIGURE 47

4" Octagonal Outlet Box Mounted on Hanger Bar


2" x 4" Studs
4" Octagonal Outlet Box
Hanger Bar
Designated Height
Box Mounting Stud

3. Attach octagonal box to hanger-bar stud

   (NOTE: Have instructor evaluate project.)

H. Carefully dismantle equipment and store in proper place; clean work area

BOXES AND ENCLOSURES
UNIT IV

JOB SHEET #2 — INSTALL OUTLET BOXES ON STEEL STUDS AND RODS, USING CADDY CLIPS

I. Equipment and materials

A. Stove bolt, ¼ inch by ½ inch

B. 3-foot piece of ½-inch EMT

C. 4-inch square outlet box, Raco #255 or equivalent

D. ½-inch EMT connector

E. Two 3-foot pieces of ¼-inch rod

F. Two rod-hanger clamps, Caddy Catalog #708-2-4 or equivalent

G. Two conduit box clips, Caddy Catalog #4-1-2-4 or equivalent

H. Medium size screwdriver

I. Electrician's hammer

II. Procedure

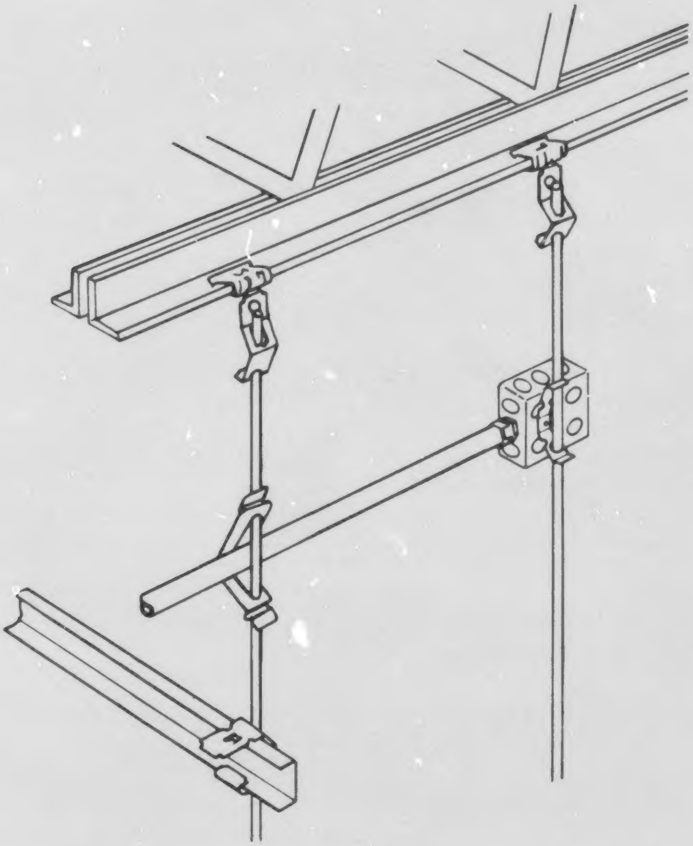
A. Install two ¼-inch rods in rod-hanger clamps

B. Mount two rod-hanger clamps on suspended angle iron approximately 24 inches apart

JOB SHEET #2

C. Install ½-inch EMT in 4-inch square box (Figure 48)

FIGURE 48



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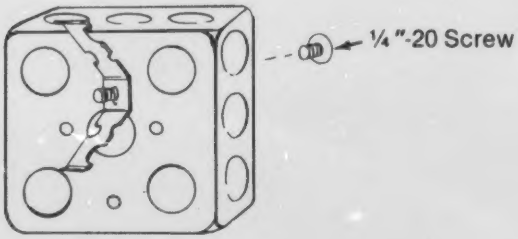
JOB SHEET #2

D. Fasten rod-hanger clip to square box (Figure 49)

FIGURE 49



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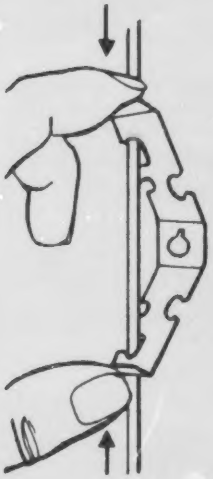
E. Mount box and EMT to the two ¼-inch rods (See Figure 50)

F. Adjust to proper height (Figure 50)

FIGURE 50



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(NOTE: Have instructor evaluate your project.)

G. Carefully dismantle your equipment and store in the proper place; clean work area

BOXES AND ENCLOSURES
UNIT IV

JOB SHEET #3 — INSTALL OUTLET BOXES ON STEEL STUDS, USING CADDY METAL STUD CLIPS FOR SWITCH BOXES

I. Equipment and materials

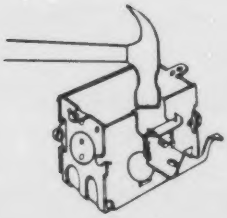
- A. Hammer
- B. 8-foot section of steel-stud wall
- C. Three electrical boxes, Raco #560 or equivalent
- D. 4-inch square electrical box, Raco #211 or equivalent
- E. Handy box, Raco #660 or equivalent
- F. Metal stud clip, Caddy #MSB-625 or equivalent
- G. Four MF clips for switch boxes, Caddy #MF-625 or equivalent

II. Procedure

(NOTE: Boxes may be mounted at nondesignated places since intent of this job sheet is to acquaint students with box mounting methods when working with steel-stud walls.)

- A. Mount metal stud clip to switch box (Figure 51)

FIGURE 51



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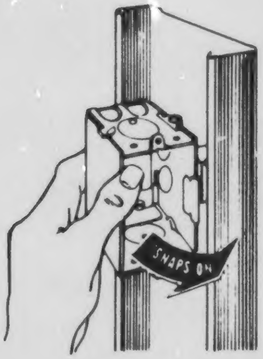
JOB SHEET #3

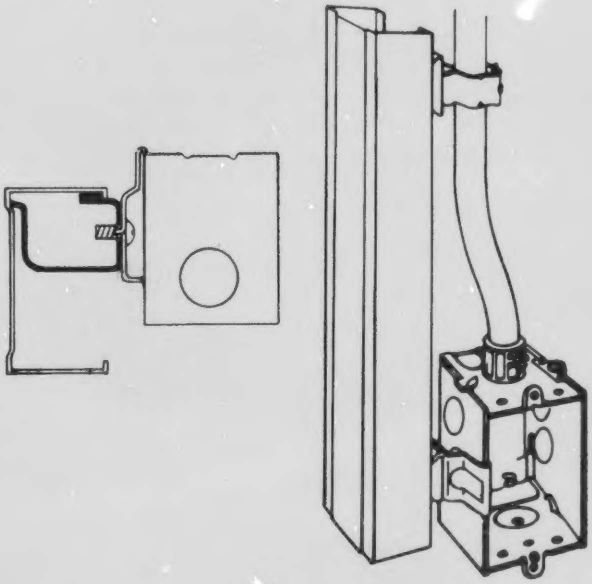
B. Mount box and clip to steel stud (Figures 52 and 53)

FIGURE 52



Used with permission of ERICO Products, Inc.

FIGURE 53

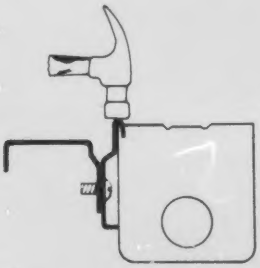


Used with permission of ERICO Products, Inc.

JOB SHEET #3

C. Mount one MF clip on each of the other boxes (Figure 54)

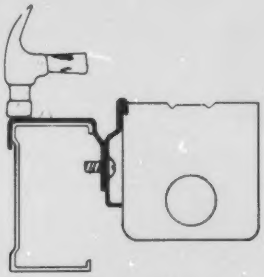
FIGURE 54



Used with permission of ERICO Products, Inc.

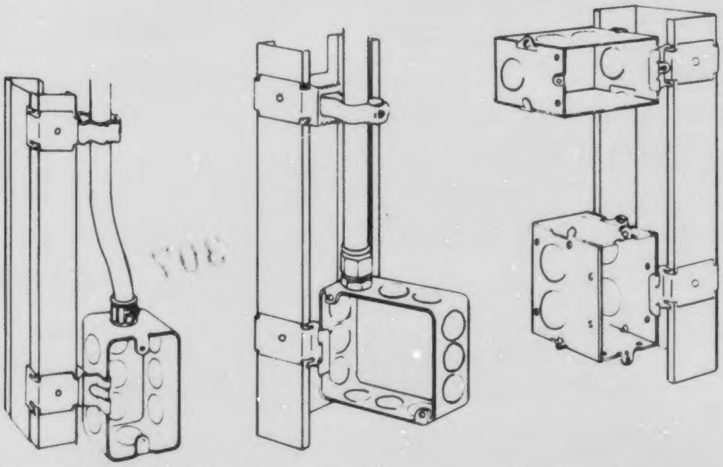
D. Mount clips and boxes to metal studs (Figures 55 and 56)

FIGURE 55



Used with permission of ERICO Products, Inc.

FIGURE 56



Used with permission of ERICO Products, Inc.

JOB SHEET #3

(NOTE: Have instructor evaluate your work.)

E. Carefully dismantle your equipment and store in the proper place; clean work area

BOXES AND ENCLOSURES
UNIT IV

JOB SHEET #4 — INSTALL MASONRY BOXES IN A BLOCK WALL

I. Equipment and materials

A. Pouch tools

B. Hacksaw

C. Two masonry switch boxes, Raco #695 or equivalent

D. Two masonry two-gang boxes, Raco #696 or equivalent

E. 20 feet of 1/2-inch EMT

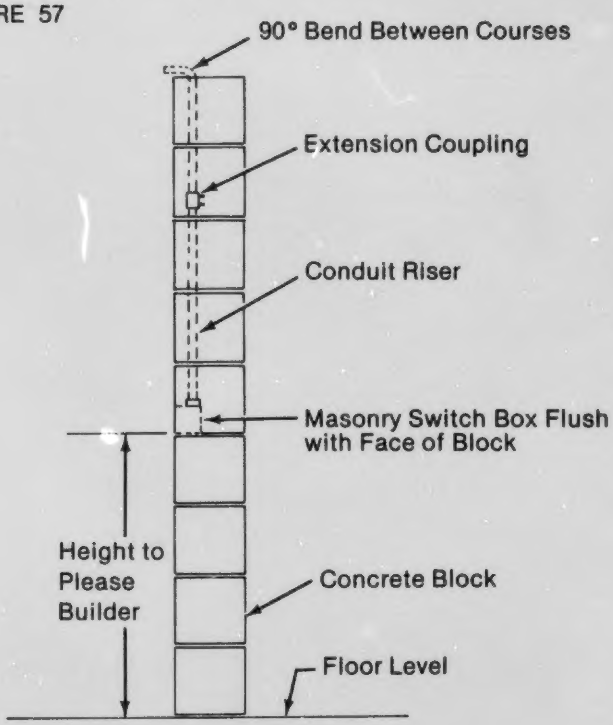
F. Four 1/2-inch EMT setscrew connectors

G. Four 1/2-inch EMT setscrew couplings

H. Conduit bender

I. Blueprint (Figure 57)

FIGURE 57


90° Bend Between Courses
Extension Coupling
Conduit Riser
Masonry Switch Box Flush with Face of Block
Height to Please Builder
Concrete Block
Floor Level

JOB SHEET #4

II. Procedure

(NOTE: This job must be done in cooperation with the masonry instructor because the electrical components are to be installed as the block wall is constructed.)

A. Open ½-inch knockout hole nearest to the back of box so that EMT will be in the hollow of the cement blocks

(NOTE: Masonry boxes generally have concentric ½-inch and ¾-inch knockout punchings; exercise care to break out only the ½-inch part.)

B. Cut eight pieces of ½-inch EMT, approximately 30 inches long

(NOTE: Cut all eight pieces exactly the same length.)

C. Install ½-inch EMT connectors in each of the four masonry box knockout holes

(NOTE: If during knockout removal, the ¾-inch punching breaks out instead of the ½-inch punching, see your instructor. You will need two ¾-inch by ½-inch reducing washers for each ¾-inch hole to properly install ½-inch EMT.)

D. Install a 30-inch piece of EMT in each connector

(NOTE: The person laying the blocks must install each block down over the vertical conduit.)

E. Deliver the made-up boxes to the block layer

(NOTE: The electrician and the block layer must work together to be sure that the boxes are installed in the proper locations, and correctly installed with the EMT extending upward in the wall. See Figure 57.)

F. When the block wall reaches desired height, install the masonry boxes with conduit extending upward

G. Supervise the installation of the next layers of blocks until only a short portion of the conduit is visible above the wall

(NOTE: The block mason must raise the blocks above the height of the conduit, and then lower the next blocks over the conduit so that it extends upward through the hollow of the blocks.)

H. Install 30-inch pieces of conduit equipped with couplings to increase the height for next layers of blocks

(NOTE: The conduit is extended upward 2 or 3 feet at a time as the height of the wall increases.

JOB SHEET #4

I. Make a 90-degree bend in the conduit when the wall and conduit reach required height

(NOTE: A 90-degree bend will allow the conduit to stick out of the wall between courses. This will prevent having to cut into the blocks.)

(NOTE: Have the instructor evaluate your work.)

J. Dismantle equipment and store in the proper place; clean work area

BOXES AND ENCLOSURES
UNIT IV

TEST

NAME ________________________________ SCORE ______________

1. Match to their correct definitions terms associated with boxes and enclosures. Write the correct numbers in the blanks. Definitions are continued on the following page.

______a. Enclosures designed for conduit or cable entrances to enclose the conductor splices and taps

______b. So constructed, protected, or treated as to prevent rain from interfering with successful operation

______c. So constructed that dust will not enter the enclosing case

______d. So constructed or protected that exposure to a beating rain will not result in the entrance of water

______e. Capable of containing hot explosive flames within the enclosure to prevent explosions in the surrounding atmosphere

______f. Electrical boxes designed for the mounting of receptacles, switches, light fixtures, or other devices

______g. Organization responsible for setting specifications for various classes of enclosures

______h. Enclosure designed either for surface or flush mounting; provided with a frame, mat, or trim in which a swinging door or doors may be hung

______i. Number of conductors of a certain size permitted in a box; number is based on cubic inches of box

______j. So constructed or protected that dust will not interfere with successful operation

______k. Boxes or enclosures made to Joint Industry Conference standards for such uses as junction boxes and housing terminal blocks

1. National Electrical Manufacturers Association (NEMA)
2. Outlet boxes
3. Cabinet
4. Dustproof
5. Joint Industry Conference (JIC) boxes
6. Raintight
7. Disconnecting means
8. NEMA enclosures
9. Junction boxes
10. Dusttight
11. Explosionproof
12. Rainproof
13. Knockout (KO)
14. Boxfill

TEST

______l. Electrical enclosures specifically designed to standards for use in specific locations and for various conditions such as indoor, outdoor, dusty, corrosive, wet, and explosive conditions

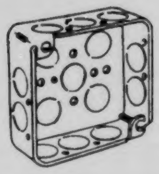
______m. Device, group of devices, or other means by which circuit conductors can be disconnected from their source of supply

______n. Partially cut out piece of metal or plastic that can be forced out when a hole is needed

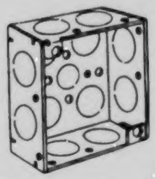
2. Identify the following classes of outlet boxes used in industrial wiring. Write the correct names in the blanks.

Octagon boxes
Regular masonry boxes
Handy boxes
Switch boxes
Masonry through-the-wall boxes
Square boxes

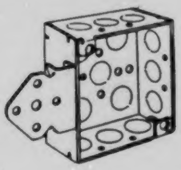
One-Piece Molded Construction



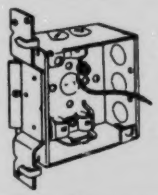
One-Piece Welded Construction



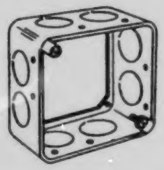
Box with Bracket



Box with Bracket, Cable Clamps, and Grounding Pigtail

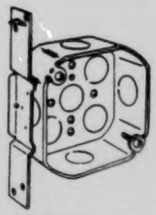
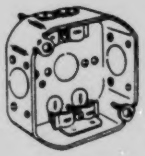
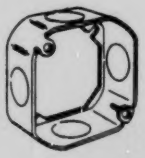
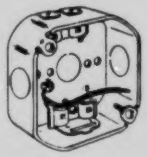
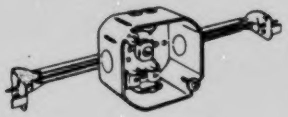


Extension



a. ______________________________

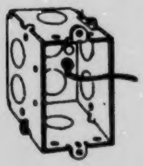
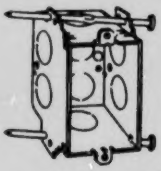
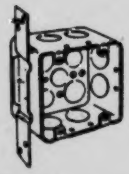
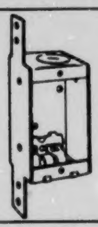
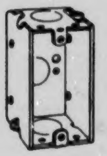
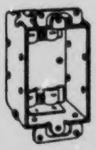
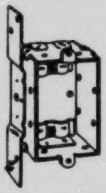
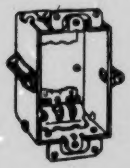
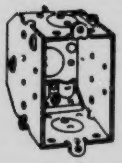
TEST

<table>
<tr><th colspan="2">Box with Bracket</th><th colspan="2">Box with Cable Clamps and Nail Holes</th><th colspan="2">Extension</th></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><th colspan="3">Box with Cable Clamps and Grounding Pigtail</th><th colspan="3">Box with Bar Hanger and Cable Clamps</th></tr>
<tr><td colspan="3"></td><td colspan="3"></td></tr>
</table>

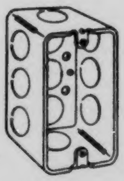
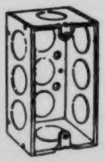
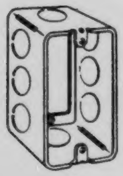
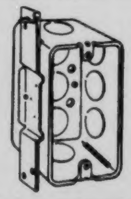
b. ____________________

TEST

c. Outlet boxes (device boxes)

Gangable with Grounding Pigtail	Nail-On	Solid Two-Gang Bracket
		
Nongangable Bracket with Cable Clamps	**Gangable with Nail Holes**	**Gangable with Ears and Cable Clamps**
		
Gangable Bracket with Cable Clamps	**Box with Drywall Grips, Cable Clamps, and Ears**	**Beveled Corner with Clamps**
		

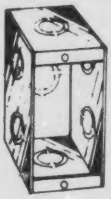
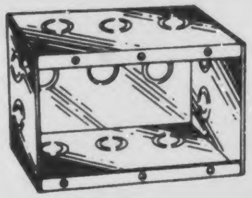
1) ____

One-Piece Molded Construction	One-Piece Welded Construction	Extension	Box with Bracket
			

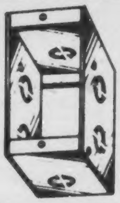
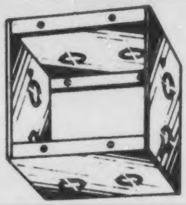
2) ____

TEST

d. Masonry boxes

Single-Gang	Three-Gang
	

1) ______________________________

Single-Gang	Two-Gang
	

2) ______________________________

3. List information needed to calculate boxfill.

a. ______________________________

b. ______________________________

c. ______________________________

4. Match the types of enclosures to their correct conditions for use. Write the correct numbers in the blanks.

______a. For use where rain or dust could interfere with normal operation

______b. For use in hazardous locations

______c. For normal use in locations without excessive dust, moisture, or corrosive atmospheres

______d. For use in locations having corrosive atmospheres

______e. For use where dust could interfere with normal operation

______f. For use in wet locations

1. Weatherproof
2. General duty
3. Corrosionproof
4. Explosionproof
5. Dustproof
6. Watertight

TEST

5. State purposes of controller enclosures.

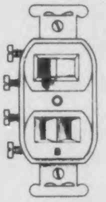
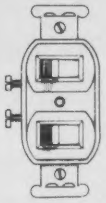
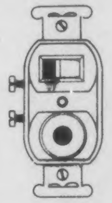
   a. ________________________________

   b. ________________________________

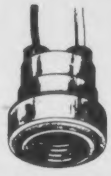
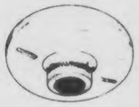
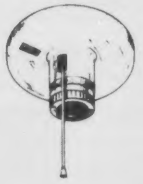
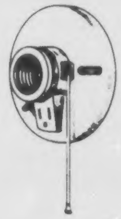
   c. ________________________________

   d. ________________________________

6. Label the following types of devices commonly used in industrial wiring.

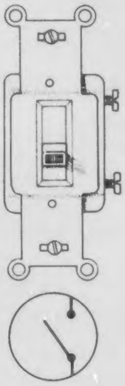
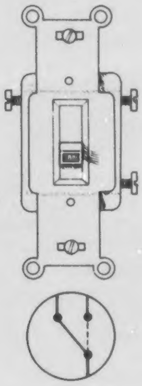
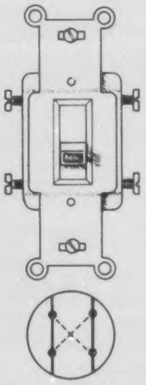
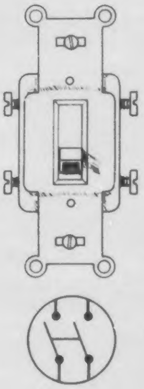
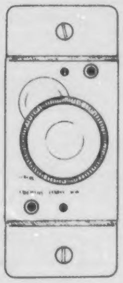
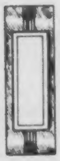
Switch and Receptacle	**Two Switches**	**Switch and Pilot Light**
		

   a. ________________________________

Keyless Pigtail	**Keyless Cover**
	
Pull-Chain Cover	**Pull-Chain Cover with Grounding-Type Receptacle**
	

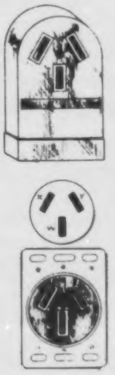
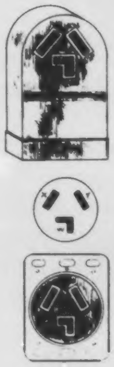
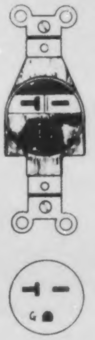
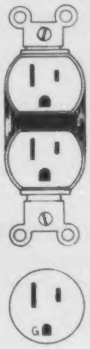
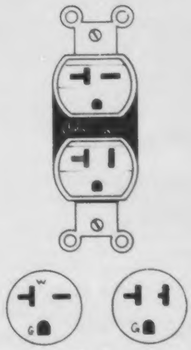
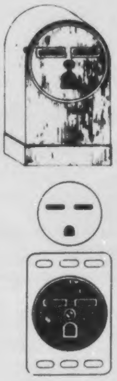
   b. ________________________________

TEST

Single Pole	Three-Way	Four-Way
		
Double Pole	**Dimmer**	**Low-Voltage Push Button**
		

c. ______________________________

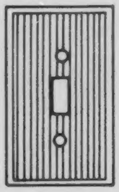
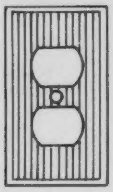
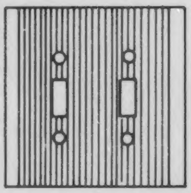
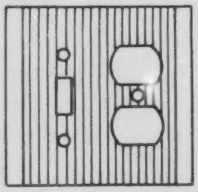
TEST

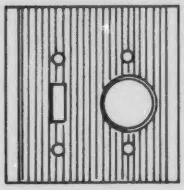
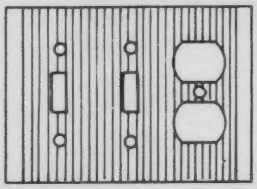
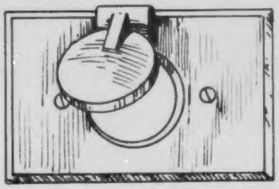
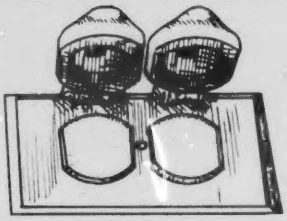
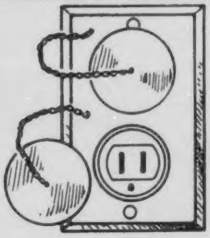
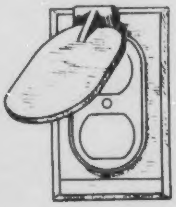
125/250 V, 50 A	125/250 V, 30 A	250 V, 20 A
		
Duplex Grounding 125 V, 15 A	Dual Voltage 125/250 V, 20 A	250 V, 30 A
		

d. ______________________________

TEST

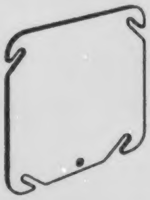
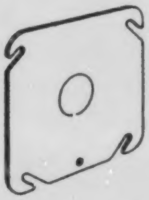
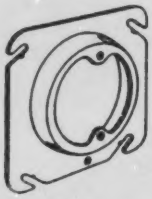
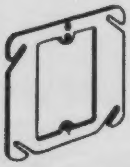
7. Label the following types of covers and plates used in electrical wiring.

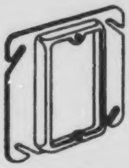
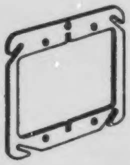
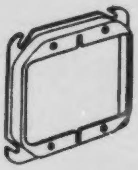
Single Toggle	Duplex Receptacle	Two-Toggle	Single Toggle and Duplex Receptacle
			

Single Toggle and Single Receptacle	Two-Toggle and Duplex Receptacle
	
Weatherproof Single Receptacle	Weatherproof Duplex Receptacle (Horizontal)
	
Weatherproof Duplex Receptacle with Screw Covers	Weatherproof Duplex Receptacle (Vertical)
	

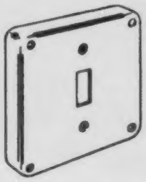
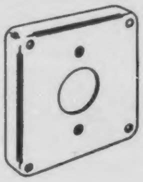
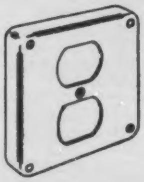
a. ____

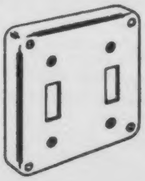
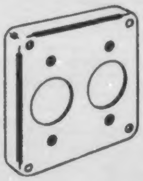
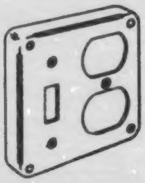
TEST

Flat Blank	Flat Blank with Knockout	Raised Open	Flat for Single Device
			

Raised for Single Device	Flat for Two Devices	Raised for Two Devices
		

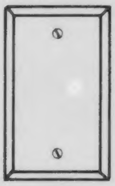
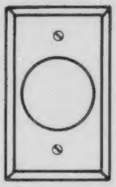
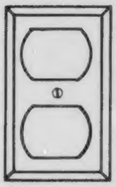
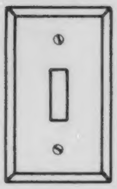
b. ____________________

Single Toggle	Single Receptacle	Duplex Receptacle
		

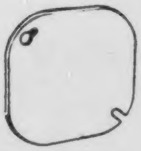
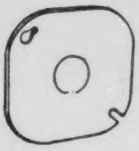
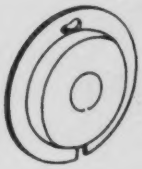
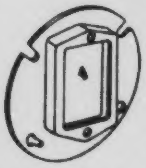
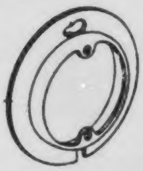
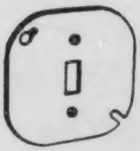
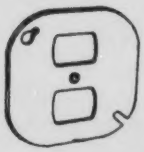
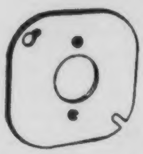
Two-Toggle	Two-Receptacle	Toggle and Duplex Receptacle
		

c. ____________________

TEST

Blank	**Single Receptacle**
	
Duplex Receptacle	**Single Toggle**
	

d. ______________________________

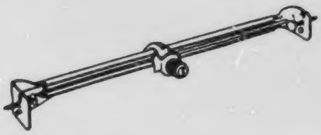
Flat Blank	**Flat Blank with Knockout**	**Raised with Knockout**	**Raised for Single Device**
			
Raised Open	**Flat Toggle**	**Flat Duplex Receptacle**	**Flat Single Receptacle**
			

e. ______________________________

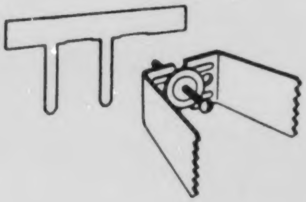
TEST

8. Identify the following supports and anchors commonly used in industrial wiring. Write the correct names in the blanks.

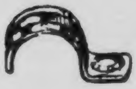
Molly bolt
Switch-box supports
Two-hole strap
Bar hanger
Drive stud
One-hole strap
Lead anchor
Plastic anchors
Toggle bolt



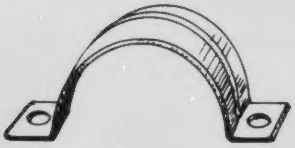
a. ____________________



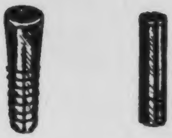
b. ____________________



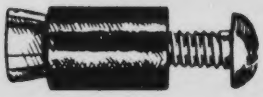
c. ____________________



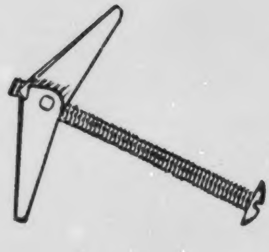
d. ____________________



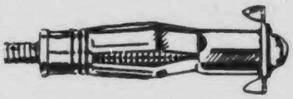
e. ____________________



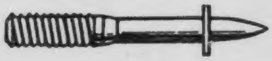
f. ____________________



g. ____________________



h. ____________________

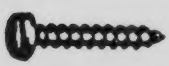


i. ____________________

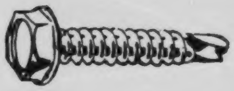
TEST

9. Identify the following screws, bolts, and nuts commonly used in industrial wiring. Write the correct names in the blanks.

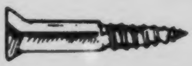
Setscrew
Wood screw
Spring nut
Wing nut
Machine screw
Single-thread nut
Sheet metal screw
Self-drilling screw
Hex-head bolt
Plain hex nut
Fixture nut
Hex-socket-head bolt
Carriage bolt
Acorn nut



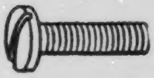
a. ____________________



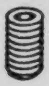
b. ____________________



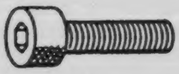
c. ____________________



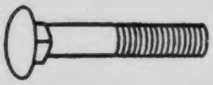
d. ____________________



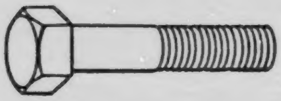
e. ____________________



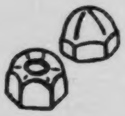
f. ____________________



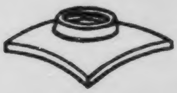
g. ____________________



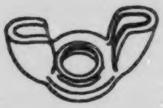
h. ____________________



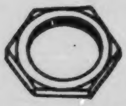
i. ____________________



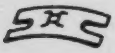
j. ____________________



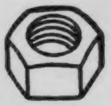
k. ____________________



l. ____________________



m. ______________________________

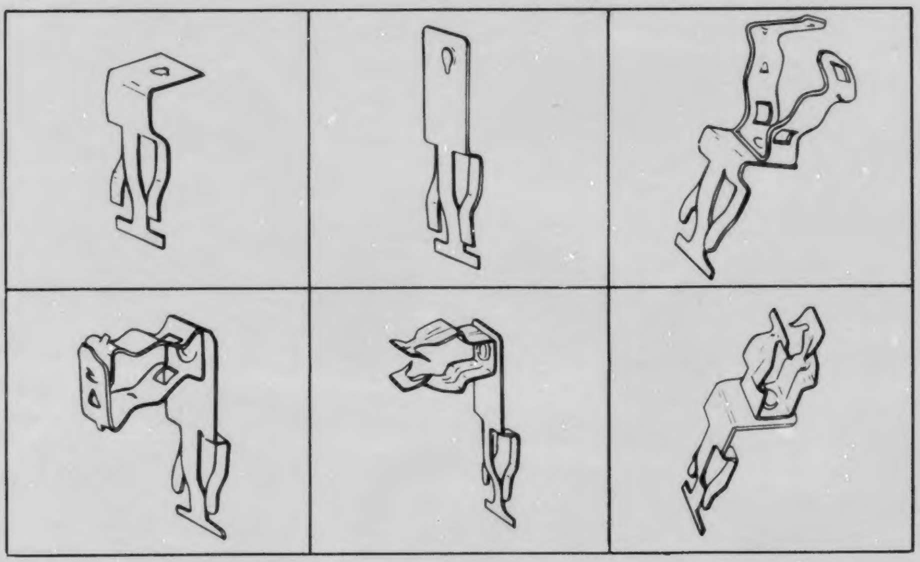


n. ______________________________

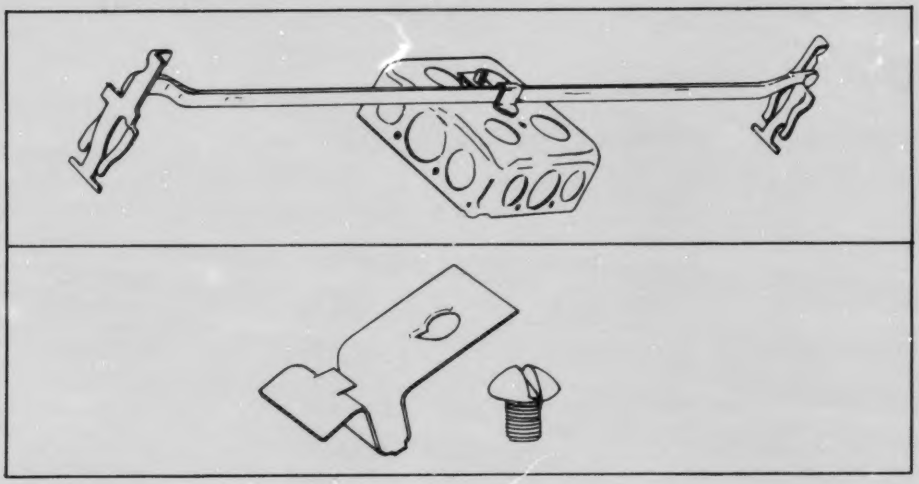
TEST

10. Identify the following classes of box-mounting devices for steel structures. Write the correct names in the blanks.

Acoustical tee-bar electrical box hanger and mounting clip
MF clip for switch boxes
Conduit box clip
Metal stud clips for switch boxes
Acoustical tee-bar clips

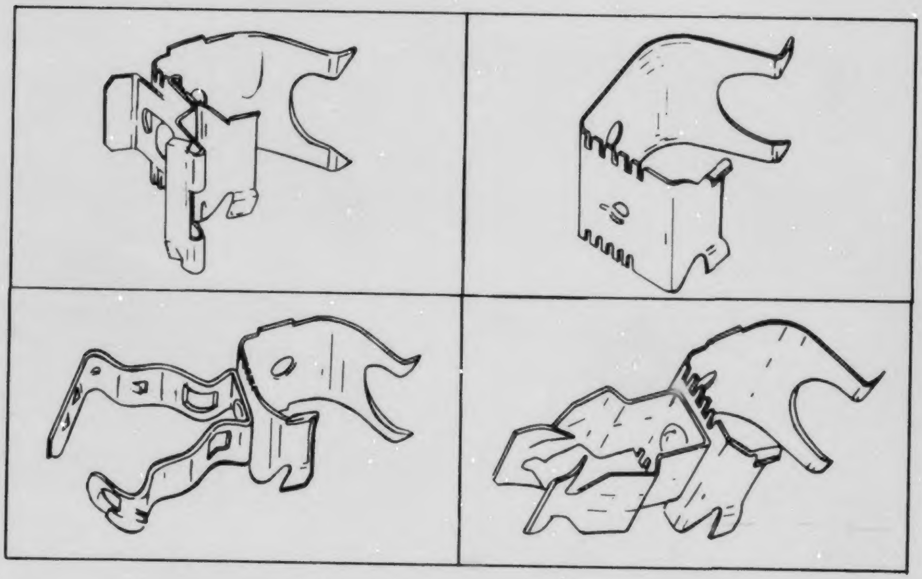


a. ____

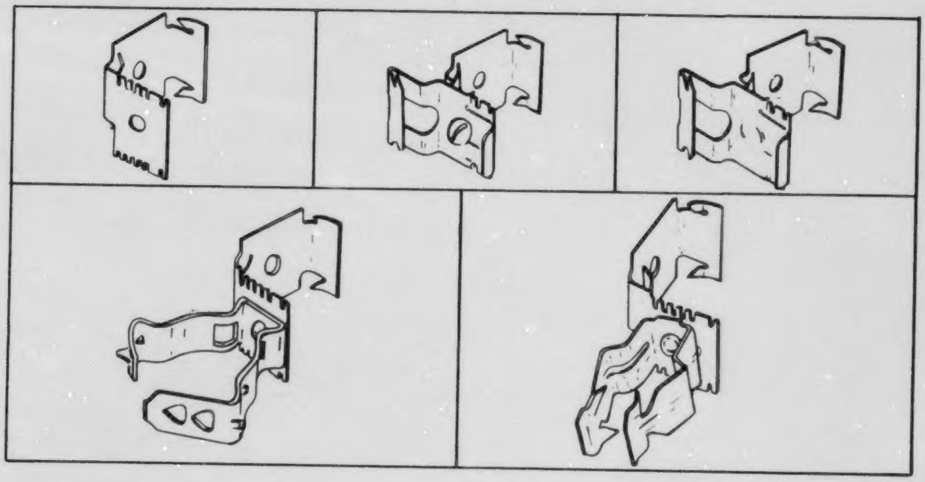


b. ____

TEST

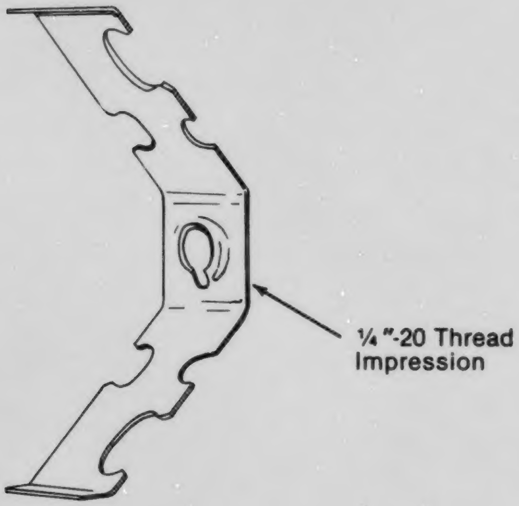


c. ______________________________



d. ______________________________

TEST



e. ______________________________

(NOTE: Test questions 11 and 12 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

11. Determine correct number of conductors for boxfill.

12. Demonstrate the ability to

    a. Install outlet boxes on wood studs on a framed wall.

    b. Install outlet boxes on steel studs and rods, using Caddy clips.

    c. Install outlet boxes on steel studs, using Caddy metal stud clips for switch boxes.

    d. Install masonry boxes in a block wall.

BOXES AND ENCLOSURES
UNIT IV

ANSWERS TO TEST

1.	a.	9	f.	2	k.	5
	b.	12	g.	1	l.	8
	c.	10	h.	3	m.	7
	d.	6	i.	14	n.	13
	e.	11	j.	4		

2. a. Square boxes
   b. Octagon boxes
   c. Outlet boxes (device boxes)
      1) Switch boxes
      2) Handy boxes
   d. Masonry boxes
      1) Regular masonry boxes
      2) Masonry through-the-wall boxes

3. a. Cubic inches of box
   b. Size of wire
   c. Number of devices and grounds

4.	a.	1	d.	3
	b.	4	e.	5
	c.	2	f.	6

5. a. Keeping boxes and enclosures clean
   b. Keeping boxes and enclosures dry

ANSWERS TO TEST

c. Protecting boxes and enclosures from accidental contact

d. Preventing injuries

6. a. Combination devices
   b. Sockets
   c. Switches
   d. Receptacles

7. a. Wall plates
   b. Square covers
   c. Exposed work raised square covers
   d. Handy box covers
   e. Round covers

8. a. Bar hanger
   b. Switch box supports
   c. One-hole strap
   d. Two-hole strap
   e. Plastic anchors
   f. Lead anchor
   g. Toggle bolt
   h. Molly bolt
   i. Drive stud

9. a. Sheet metal screw
   b. Self-drilling screw
   c. Wood screw
   d. Machine screw
   e. Setscrew
   f. Hex-socket-head bolt
   g. Carriage bolt
   h. Hex-head bolt
   i. Acorn nut
   j. Spring nut
   k. Wing nut
   l. Fixture nut
   m. Single-thread nut
   n. Plain hex nut

ANSWERS TO TEST

10.
   a. Acoustical tee-bar clips
   b. Acoustical tee-bar electrical box hanger and mounting clip
   c. Metal stud clips for switch boxes
   d. MF clips for switch boxes
   e. Conduit box clip

11. Evaluated to the satisfaction of the instructor

12. Performance skills evaluated to the satisfaction of the instructor

IN-PLANT DISTRIBUTION SYSTEMS
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to identify in-plant distribution systems, connect three transformers in a delta-delta configuration, and connect transformer primary and secondary windings in a delta-wye configuration. The student will show this knowledge by completing the assignment sheet, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with in-plant distribution systems.
2. State items to consider when planning an in-plant distribution system.
3. Name the most commonly used in-plant voltage systems.
4. Distinguish between advantages and disadvantages of commonly used voltage systems.
5. State general uses of the open-delta system.
6. Name principal uses of direct-current power in a plant.
7. Select from a list safety measures to be used with systems over 600 volts.
8. State reasons for using capacitors.
9. State rules for wye-system voltages and currents.
10. State rules for delta-system voltages and currents.
11. Sketch transformer connections for in-plant voltage distribution systems.
12. Demonstrate the ability to
    a. Connect three transformers in a delta-delta configuration.
    b. Connect transformer primary and secondary windings in a delta-wye configuration.

IN-PLANT DISTRIBUTION SYSTEMS
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Make transparencies.

   B. Provide students with objective sheet.

   C. Discuss unit and specific objectives.

   D. Provide students with information, assignment, and job sheets.

   E. Discuss information and assignment sheets.

      1. Discuss terms and definitions, using Information Sheet, Section I. Stress the importance of good comprehension of the meanings of typical terms used in industry. These terms are the basis of communication between industrial electricians and most specifying engineers.

      2. Discuss the items to be used when planning an in-plant distribution system. Make sure to discuss with the students that these considerations are not only for safety, but for future service for the customer.

      3. Discuss the most commonly used in-plant voltage system, using Assignment Sheet #1 and Transparencies #1 through #3 and #5 and #6. Be sure to stress the importance of the particular voltages that are associated with wye and delta systems. At this point, the students should be able to describe the typical voltage configuration simply by knowing whether the system is wye or delta.

      4. Discuss advantages and disadvantages of commonly used voltage systems. During your discussion, be sure to stress that every plant presents a unique situation. No two plants or industrial sites are the same; therefore, each plant system must be custom-designed for that particular plant. By understanding the advantages and disadvantages of each system, students will be able to decide which system would be best for their purpose.

      5. Discuss general uses of the open-delta system, using Transparency #4. During this discussion, stress the primary difference between open-delta and closed-delta systems.

      6. Discuss the principal uses of DC power in an industrial plant. Explain that DC power is becoming less prevalent in today's plants because of the new solid-state switching for AC motors. Solid-state switching provides speed control, presently one of the primary functions of DC.

SUGGESTED ACTIVITIES

7. Discuss safety measures to be used in systems over 600 volts. Be sure that the students understand that when 600 volts are exceeded, the possibility for arcing, burns, and physical injury becomes more prevalent. The higher voltage has the potential to travel a greater distance across an insulator such as air or even rubber or plastic.

8. Discuss reasons for using capacitors. Show students a capacitor, and set it up in the shop to show the voltage change when a capacitor is put in the circuit.

9. Discuss the rules for wye-system voltages and currents, using Information Sheet, Section IX. Remind the students that normally when dealing with wye systems they are dealing with three phase, but make sure that they understand that single phase can be taken from this particular wye system.

10. Discuss rules for delta-system voltages and currents. Stress that the delta system has one wild leg, which normally reads 207 volts from ground to the wild leg. Remind the students that should a single-phase source for 120 volts be hooked up to the wild leg, equipment burnout and possible damage to the operator might occur.

11. Discuss transformer connections for typical in-plant voltage distribution systems. Make sure that the student has a complete understanding of the difference between wye, closed delta, and open delta. Explain how these systems can be combined, depending upon the setup of the windings. Usually the power company can be helpful in assisting you with cutaway views of trasformers and diagrams of transformer windings. Most power companies in your area would be happy to give you a transformer hookup book for pictures, and possibly even a cutaway transformer for viewing in the shop.

12. Discuss and demonstrate the connection of three-phase transformers in a delta configuration and the connection of transformer primary and secondary windings and wye connections. Make sure that the student understands that these are typical setups that they will find in industry. Have available the proper transformers to demonstrate these connections, and allow students to experiment with their own connections.

F. Take students on at least two field trips to industrial plants in your area; have students pay particular attention to the electrical system and equipment in each plant.

G. Demonstrate and discuss procedures outlined in job sheets.

H. Furnish students with material and equipment to perform job sheet activities.

SUGGESTED ACTIVITIES

- I. Give test.
- J. Reteach and retest if necessary.

II. Instructional materials

- A. Objective sheet
- B. Suggested activities
- C. Information sheet
- D. Transparency masters
  1. TM #1 — Single-Phase AC Three-Wire System for 120/240-Volt Power Supply
  2. TM #2 — Three-Phase Four-Wire Wye System for 120/208-Volt Power Supply
  3. TM #3 — Three-Phase Four-Wire Delta System for 120/240-Volt Power Supply
  4. TM #4 — Four-Wire Open-Delta System for 240/480-Volt Power Supply
  5. TM #5 — Three-Phase Four-Wire Wye System for 277/480-Volt Power Supply
  6. TM #6 — Three-Phase Four-Wire Delta System for 240/480-Volt Power Supply
- E. Assignment Sheet #1 — Sketch Transformer Connections for In-Plant Voltage Distribution Systems
- F. Answers to assignment sheet
- G. Job sheets
  1. Job Sheet #1 — Connect Three Transformers in a Delta-Delta Configuration
  2. Job Sheet #2 — Connect Transformer Primary and Secondary Windings in a Delta-Wye Configuration

SUGGESTED ACTIVITIES

H. Test

I. Answers to test

III. Unit references

A. Adams, James E. *Electrical Principles and Practices*, 2nd ed. New York: McGraw-Hill Book Co., 1973.

B. *National Electrical Code*. Boston, Massachusetts: National Fire Protection Association, 1981.

C. *Westinghouse-Electrical Maintenance Hints*. Trafford, Pennsylvania: Westinghouse Electric Corporation, Printing Division, 1974.

IN-PLANT DISTRIBUTION SYSTEMS
UNIT I

INFORMATION SHEET

I. Terms and definitions

   A. Voltage system — Method of making transformer connections to obtain desired voltage

   B. In-plant power distribution system (premises wiring system) — Interior and exterior wiring that extends from load end of service drop; includes all associated hardware, fittings, and wiring devices

   C. Grounded — Connected to earth or to some conducting body that serves in place of earth

   D. Voltage regulation — Ability to hold a set voltage within a set tolerance

   E. Power factor — Ratio of true power (watts) to apparent power (volt-amperes)

   F. Capacitor — Device used to shift phase of inductive load

II. Items to consider when planning an in-plant distribution system

   A. Service dependability

   (NOTE: Adequate sizing and fuse coordination are needed to furnish dependable electric service to various plant equipment.)

   B. Flexibility

   (NOTE: System needs to be constructed with adequate power throughout plant to allow for moving equipment or adding equipment without major expense.)

   C. Voltage regulation

   (NOTE: Capacity is needed to deliver proper voltage to all equipment without excessive voltage drop.)

   D. Allowance for growth

   (NOTE: System should allow for expansion and future additional capacity that will not disturb the existing system.)

   E. Safety

   (NOTE: System needs to be installed to meet standards of current *National Electrical Code*.)

INFORMATION SHEET

F. Efficiency

(NOTE: Conductors and equipment must have minimum heat or power loss and acceptable power factor.)

G. Initial costs

EXAMPLE: Does the system cost exceed allowable funds or make it an unsound investment?

H. Operating and maintenance costs

EXAMPLE: Are there provisions for planned maintenance?

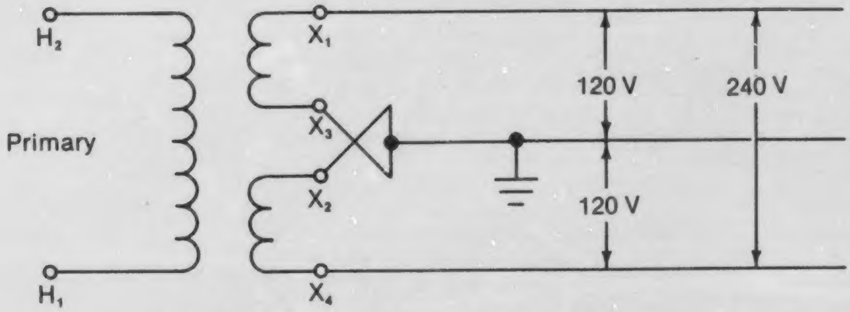
III. Most commonly used in-plant voltage systems (Figures 1-3; Assignment Sheet #1; Transparencies #1-#3 and #5 and #6)

A. Single-phase AC three wire

(NOTE: This system is usually used for small commercial locations. It consists of a three-wire 120/240-volt service with switchboard or panelboard and breakers to power branch circuits.)

EXAMPLE:

FIGURE 1



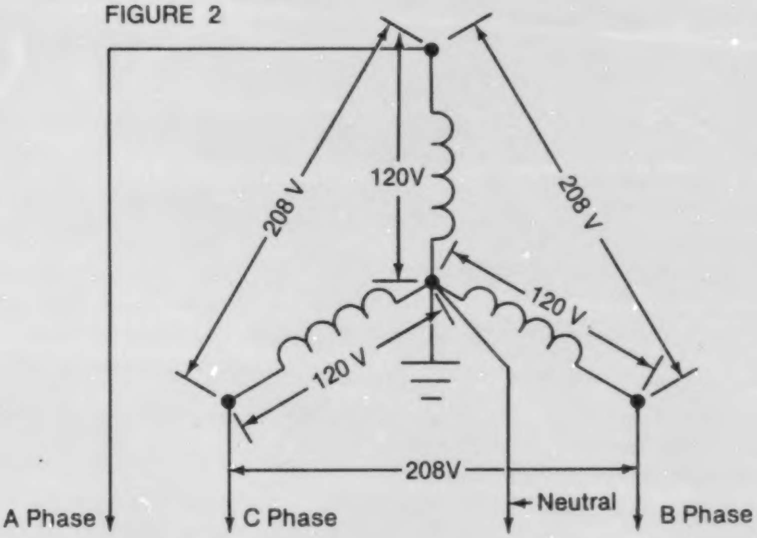
INFORMATION SHEET

B. Three-phase wye with neutral grounded

(NOTE: This system usually has 120/208-volt or 277/480-volt power supply.)

EXAMPLE:

FIGURE 2

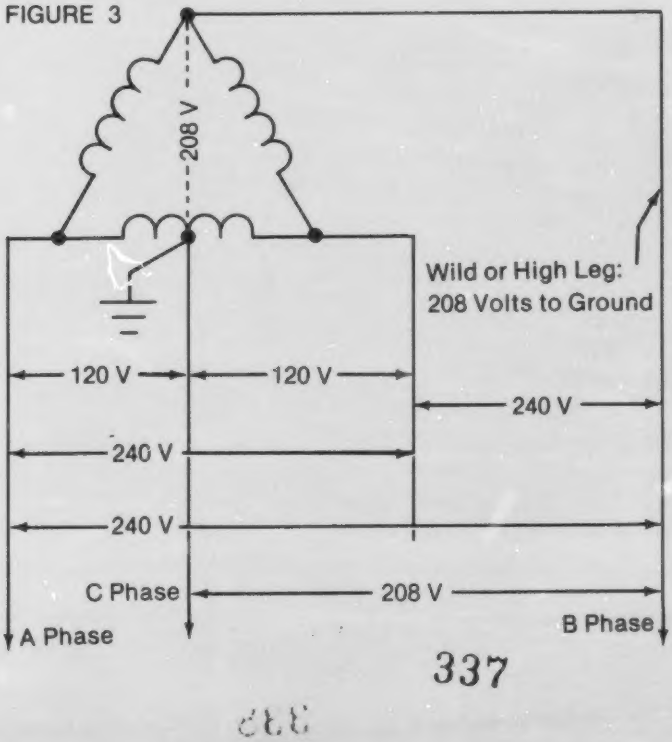

208 V
120V
208 V
120 V
120 V
208V
A Phase
C Phase
Neutral
B Phase

C. Three-phase delta

(NOTE: This system usually has 120/240-volt or 480-volt power supply.)

EXAMPLE:

FIGURE 3


208 V
Wild or High Leg:
208 Volts to Ground
120 V
120 V
240 V
240 V
240 V
C Phase
208 V
A Phase
B Phase

INFORMATION SHEET

IV. Advantages and disadvantages of commonly used voltage systems

- A. Single-phase AC three wire
  - 1. Advantages
    - a. Is simple to maintain
    - b. Contains fewer fault currents than other systems
    - c. Requires less expensive distribution equipment
  - 2. Disadvantages
    - a. Is easy to overload
    - b. Limits plant to single-phase motors
    - c. May be expensive to expand
- B. Three-phase wye
  - 1. Advantages
    - a. Is flexible
    - b. Contains minimum variety in size of wire and conduit
    - c. Has good voltage regulation
    - d. Uses economical motors
    - e. Is easy to balance system load
    - f. Provides simple and effective means of suppressing damaging transient line-to-ground overvoltages
    - g. May use all three phases for 120-volt circuits
  - 2. Disadvantages
    - a. Requires neutral to be firmly grounded
    - b. May contain excessive fault currents
    - c. Some equipment must be special ordered for 208-volt

INFORMATION SHEET

C. Three-phase delta

   1. Advantages

      a. Has good voltage regulation

      b. Does not require grounding

      c. Can be operated on open delta at reduced load if transformer fails

      d. Uses economical motors

   2. Disadvantages

      a. Is difficult to balance system load

      b. Has wild or high leg if midpoint of one transformer is grounded

      (NOTE: Voltage of high leg is 1.73 times other leg to ground.)

      c. Is less flexible than other systems

V. General uses of the open-delta system (Transparency #4)

   A. Serving a predominantly single-phase load, possibly with one three-phase motor

   B. Restoring reduced power to a three-phase system when a transformer fails

VI. Principal uses of direct-current power in a plant

   A. Motors

   EXAMPLES: Crane or hoist motors; where speed control is essential

   B. Control circuits

   EXAMPLE: Magnetic DC braking

VII. Safety measures to be used with systems over 600 volts

   A. Provide greater working clearances than for lower-voltage systems

   (NOTE: See 1981 *NEC*, Table 110-34 [a].)

   B. *Do not* open under load any expulsion-type cutouts or fuse links

   C. Test all phases for voltage (phase-to-phase and phase-to-ground) before starting any work

   (NOTE: See 1981 *NEC*, Section 710.)

INFORMATION SHEET

D. Ground each phase before handling conductors or equipment

VIII. Reasons for using capacitors

A. To improve power factor

B. To reduce electricity costs

C. To reduce system load amperes

IX. Rules for wye-system voltages and currents (Figures 4 and 5)

(NOTE: The number 1.73 is used as a constant when determining transformer capacities in three-phase systems.)

A. Line voltage equals coil voltage times 1.73

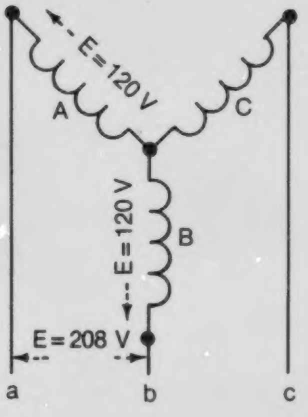
B. Phase voltage equals line voltage divided by 1.73

C. Line current equals coil current

D. Total circuit current equals line amperes times 1.73

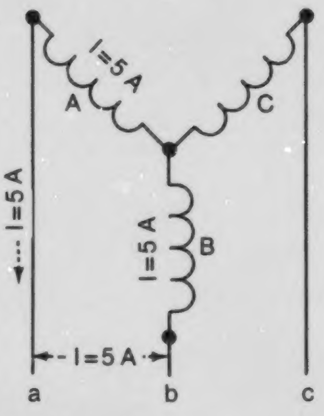
EXAMPLES: Wye-wye systems

FIGURE 4



(a)

FIGURE 5



(b)

X. Rules for delta-system voltages and currents (Figures 6-9)

A. Line current equals coil current times 1.73

B. Coil current equals line current divided by 1.73

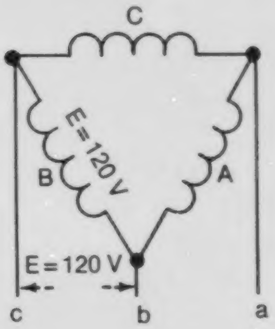
INFORMATION SHEET

C. Line voltage equals coil voltage

D. Total circuit current equals line amperes times 1.73

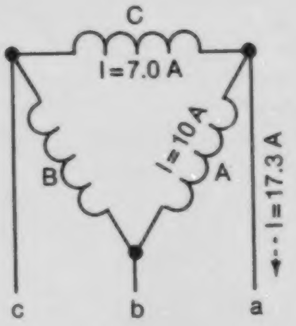
EXAMPLES: Delta-delta systems

FIGURE 6


C
E=120 V
B
A
E=120 V
c
b
a

(a)

FIGURE 7


C
I=7.0 A
I=10 A
B
A
I=17.3 A
c
b
a

(b)

EXAMPLES: Wye-delta systems

FIGURE 8

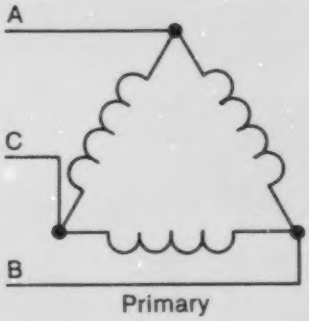
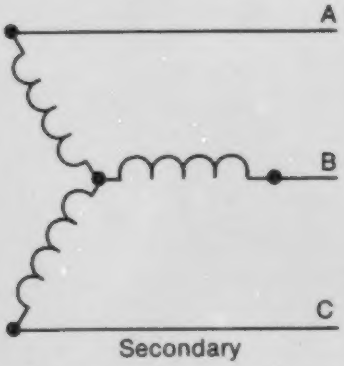
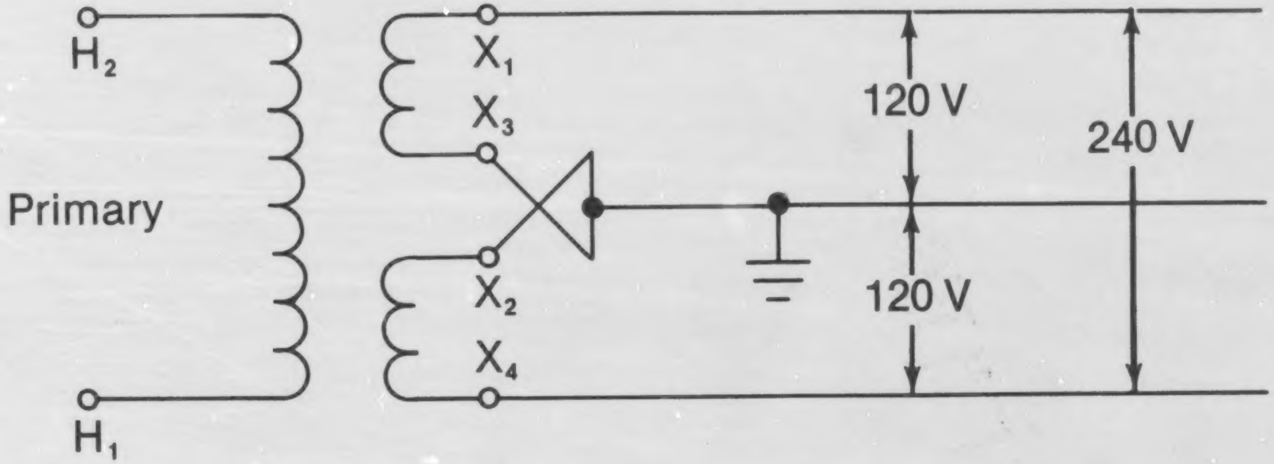

A
C
B
Primary

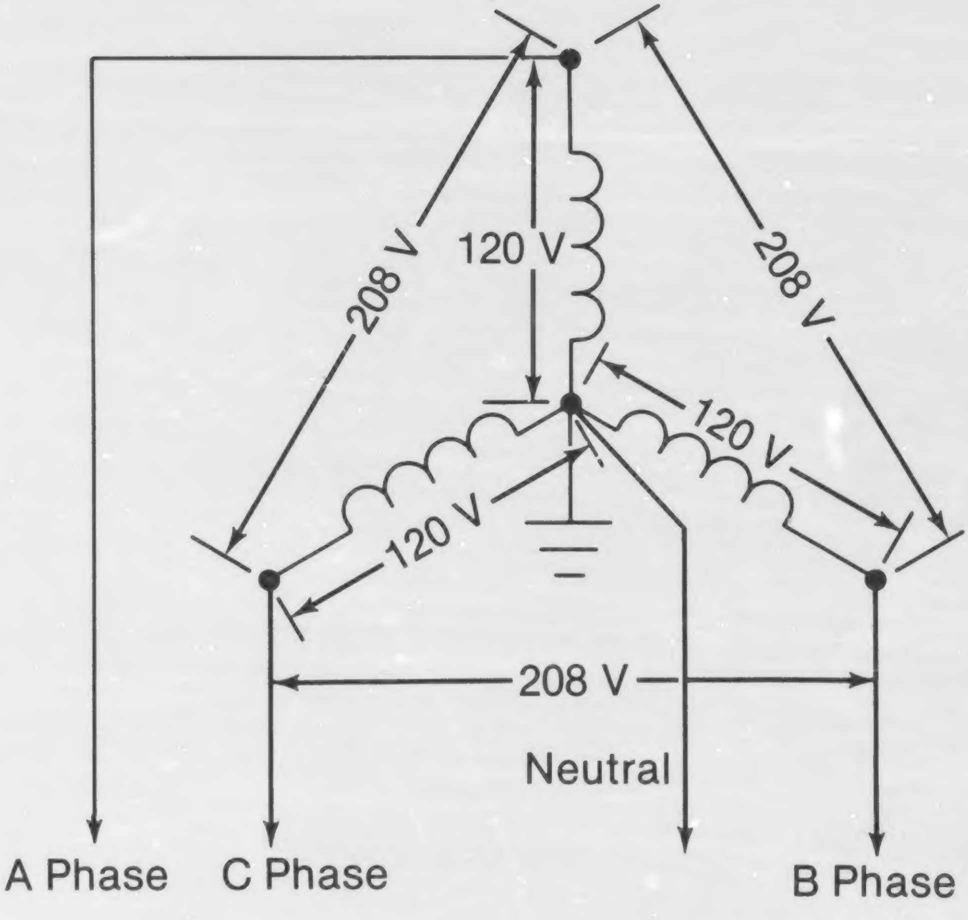
FIGURE 9


A
B
C
Secondary

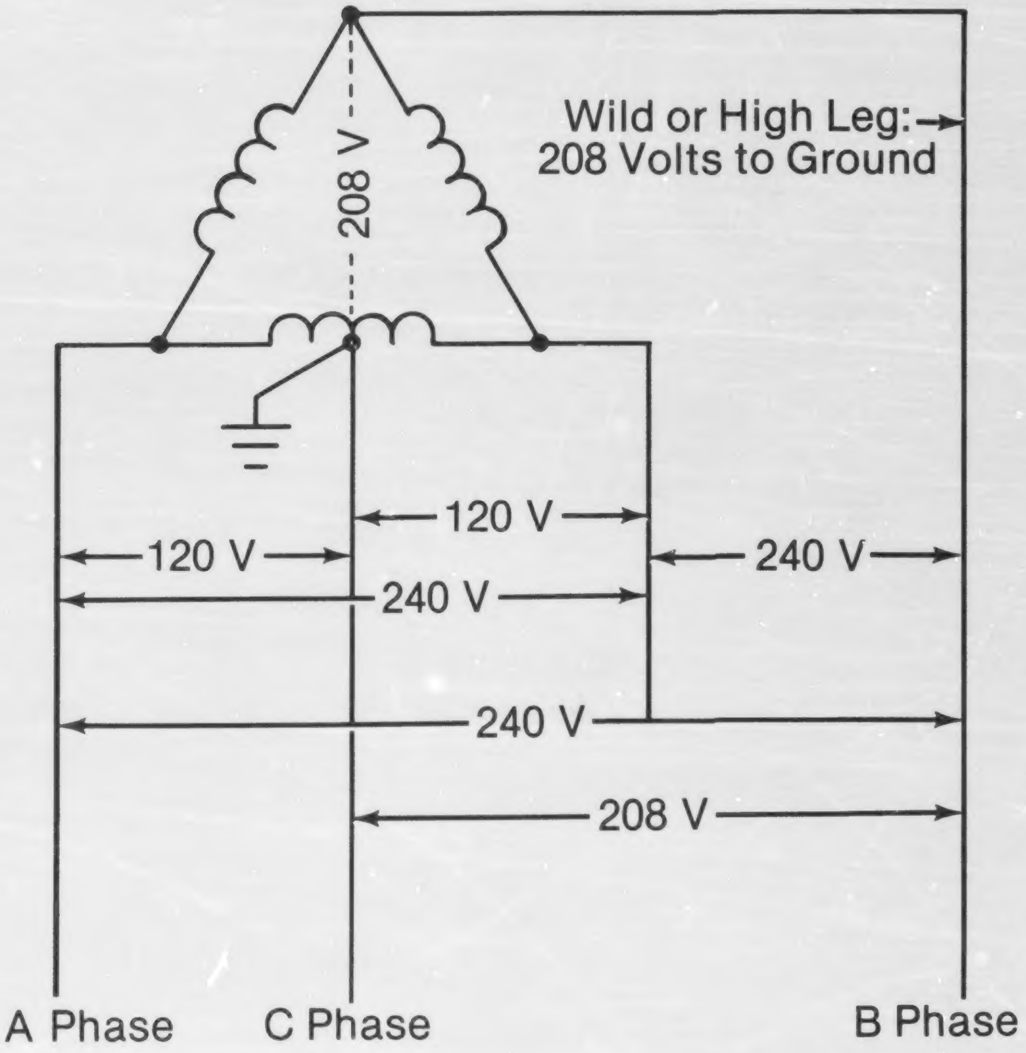
Single-Phase AC Three-Wire System for 120/240-Volt Power Supply


H_2
X_1
X_3
120 V
240 V
Primary
X_2
120 V
X_4
H_1

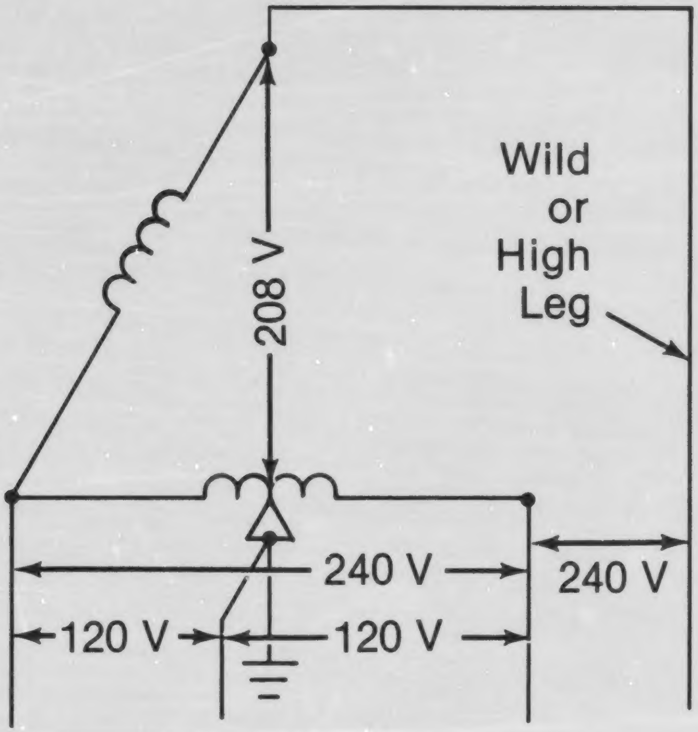
Three-Phase Four-Wire Wye System for 120/208-Volt Power Supply

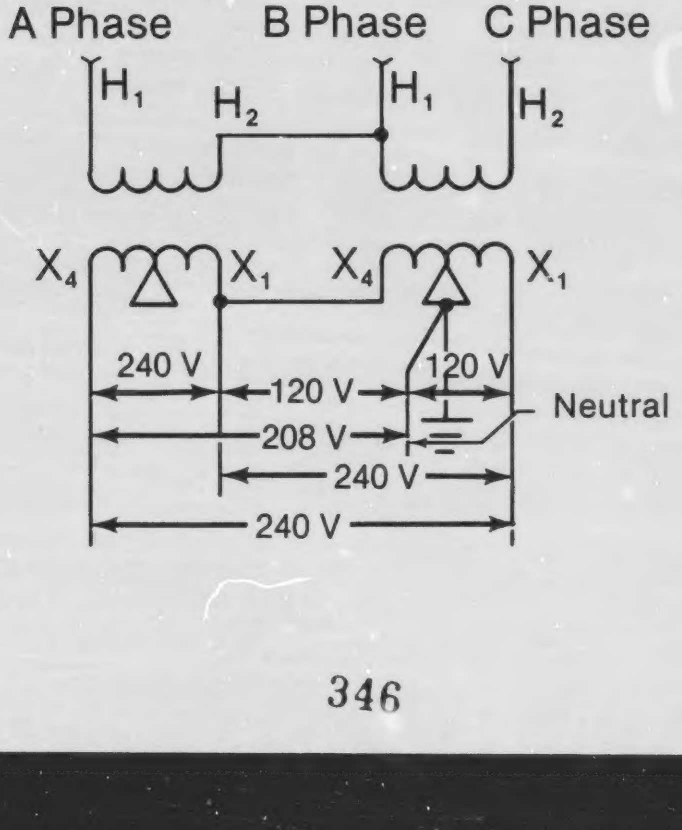

208 V
120 V
208 V
120 V
120 V
208 V
Neutral
A Phase
C Phase
B Phase

Three-Phase Four-Wire Delta System for 120/240-Volt Power Supply

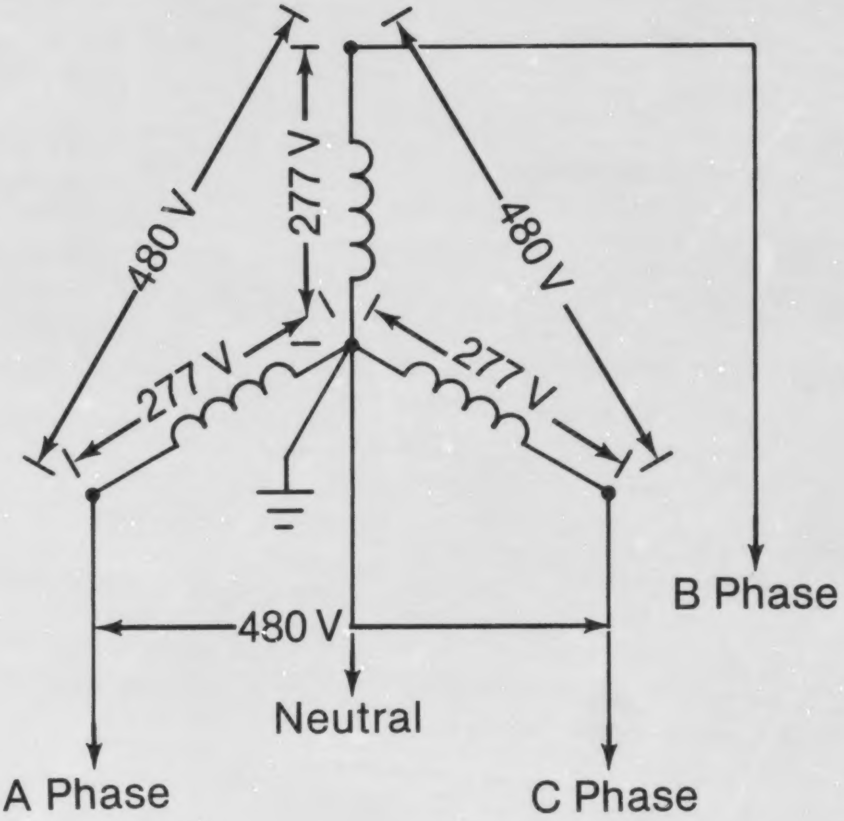

208 V
Wild or High Leg: 208 Volts to Ground
120 V
120 V
240 V
240 V
240 V
208 V
A Phase
C Phase
B Phase

Four-Wire Open-Delta System for 240/480-Volt Power Supply

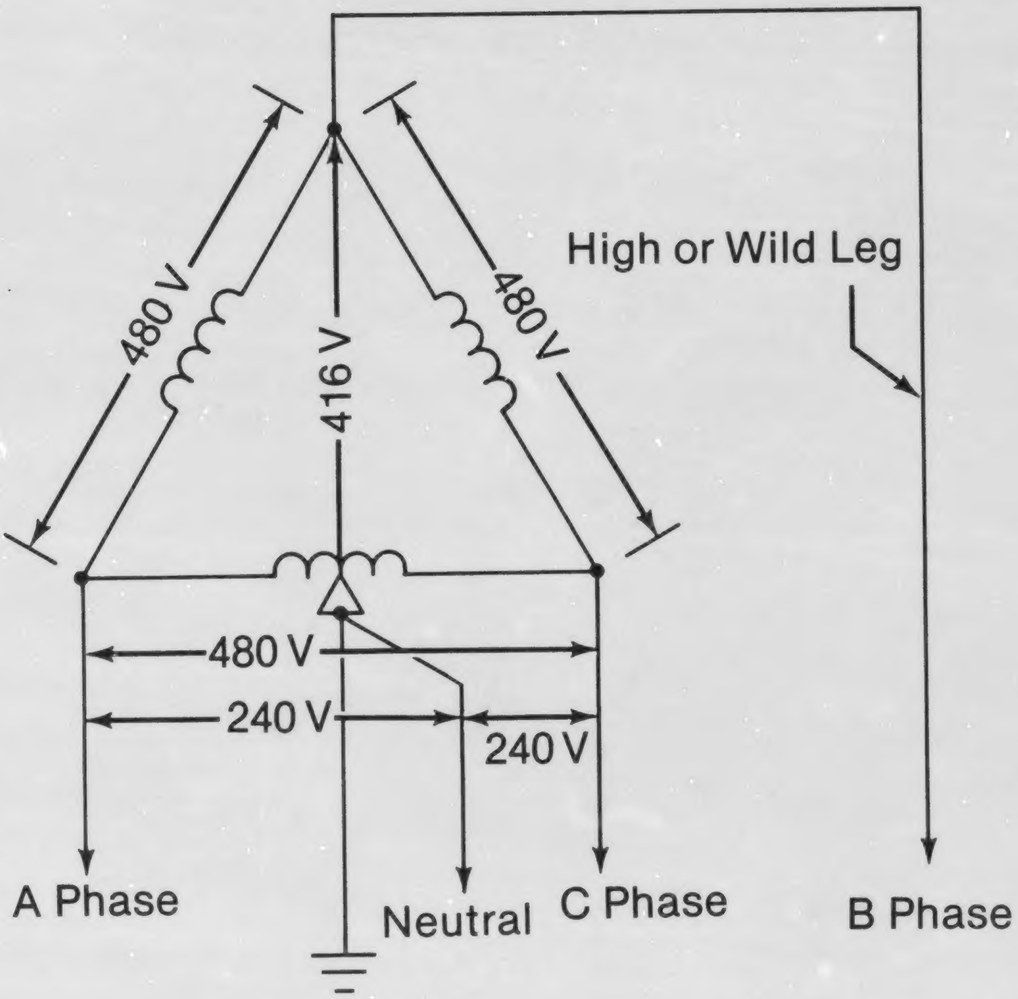

Wild
or
High
Leg
208 V
240 V
240 V
120 V
120 V


A Phase
B Phase
C Phase
H_1
H_2
H_1
H_2
X_4
X_1
X_4
X_1
240 V
120 V
120 V
Neutral
208 V
240 V
240 V

Three-Phase Four-Wire Wye System for 277/480-Volt Power Supply


480 V
277 V
480 V
277 V
277 V
B Phase
480 V
Neutral
A Phase
C Phase

Three-Phase Four-Wire Delta System for 240/480-Volt Power Supply


480 V
416 V
480 V
High or Wild Leg
480 V
240 V
240 V
A Phase
Neutral
C Phase
B Phase

IN-PLANT DISTRIBUTION SYSTEMS
UNIT I

ASSIGNMENT SHEET #1 — SKETCH TRANSFORMER CONNECTIONS FOR IN-PLANT VOLTAGE DISTRIBUTION SYSTEMS

NAME ____ SCORE ________________

For personal safety and efficiency, the technician should be able to sketch transformer connections for primary and secondary in-plant voltage systems.

A. Make a sketch of a single-phase transformer connection. Label voltages.

ASSIGNMENT SHEET #1

B. Make a sketch of a three-phase wye transformer connection with midpoint grounded. Label voltages.

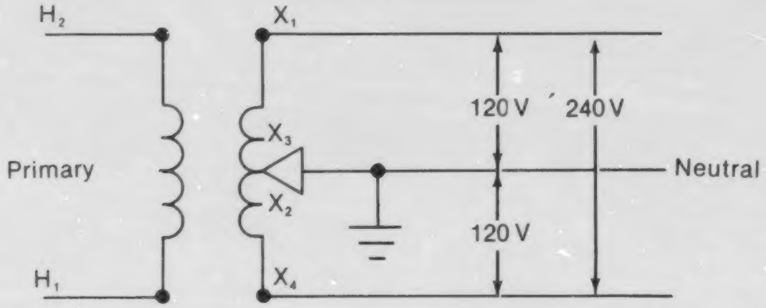
C. Make a sketch of a three-phase delta transformer connection with midpoint of one phase grounded. Label voltages.

IN-PLANT DISTRIBUTION SYSTEMS
UNIT I

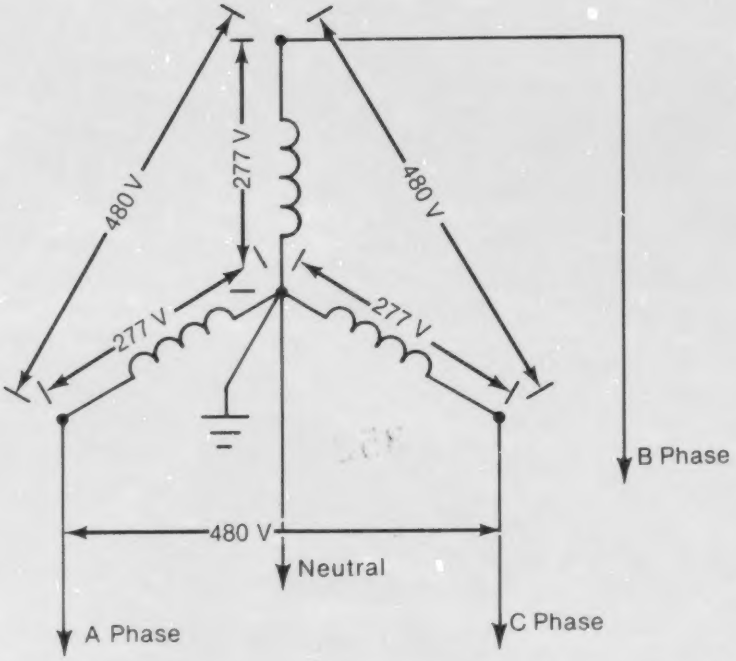
ANSWERS TO ASSIGNMENT SHEET #1

Assignment Sheet #1

A.

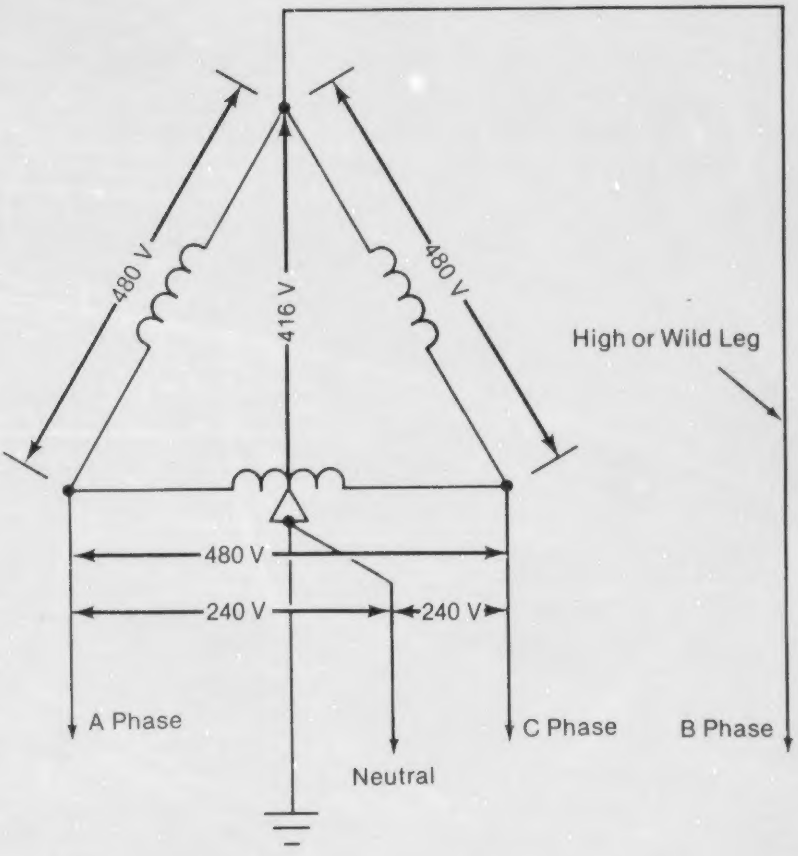

H₂
X₁
120 V
240 V
X₃
Primary
Neutral
X₂
120 V
H₁
X₄

B.


480 V
277 V
480 V
277 V
277 V
B Phase
480 V
Neutral
A Phase
C Phase

ANSWERS TO ASSIGNMENT SHEET

C.


480 V
416 V
480 V
High or Wild Leg
480 V
240 V
240 V
A Phase
C Phase
B Phase
Neutral

IN-PLANT DISTRIBUTION SYSTEMS
UNIT I

JOB SHEET #1 — CONNECT THREE TRANSFORMERS IN A DELTA-DELTA CONFIGURATION

I. Equipment and materials

A. Three-phase power supply, 240-volt

(NOTE: A three-phase 208-volt power supply will also serve satisfactorily.)

B. Three 5-ampere fuses in 240-volt circuit

C. #14 wire, approximately 20 feet

D. Wire nuts or bolts for connections

E. Three transformers rated 240 to 120/240 at 1 kilovolt-ampere

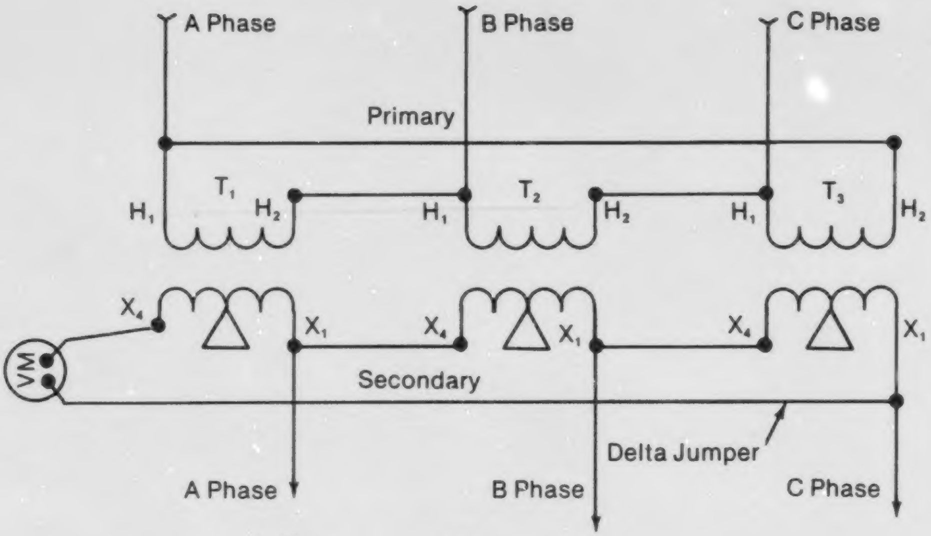
F. Voltmeter with 600-volt scale

II. Procedure

A. Connect transformers as shown in Figure 10

(NOTE: Leave X1 of T3 open for polarity test.)

FIGURE 10


A Phase
B Phase
C Phase
Primary
T_1
H_1
H_2
T_2
H_1
H_2
T_3
H_1
H_2
X_4
X_1
X_4
X_1
X_4
X_1
VM
Secondary
Delta Jumper
A Phase
B Phase
C Phase

JOB SHEET #1

B. Check connections for correctness; make sure that all leads are clear and that voltmeter is set on 600-volt scale

C. Connect primary leads A, B, and C to L1, L2, and L3 of 240-volt power supply

(NOTE: Show work to instructor before proceeding.)

D. Energize 240-volt circuit

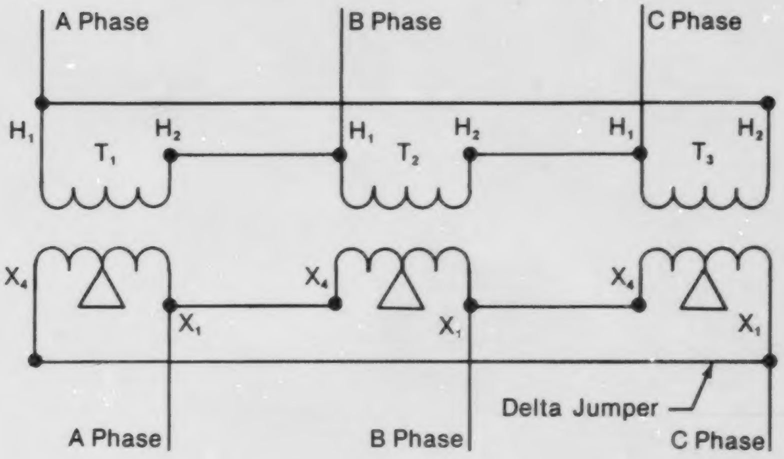
E. Read voltmeter

(NOTE: Voltmeter should read zero or twice the secondary volts. If voltmeter reads zero, move voltmeter leads to primary leads A and B and read again. This procedure tests both the power supply and voltmeter. If tests show volts normal between primary phases A and B and zero at the open connection on the secondary, the delta-delta connections and polarity of transformers are correct.)

F. Deenergize transformer

G. Close the connection between the delta jumper and X1 of T3 (Figure 11)

FIGURE 11


A Phase
B Phase
C Phase
H_1
T_1
H_2
H_1
T_2
H_2
H_1
T_3
H_2
X_4
X_1
X_4
X_1
X_4
X_1
Delta Jumper
A Phase
B Phase
C Phase

JOB SHEET #1

H. Energize the 240-volt circuit

I. Using voltmeter, read and record primary voltage

Phases A to B ____________________

Phases A to C ____________________

Phases B to C ____________________

J. Using voltmeter, read and record secondary voltage

Phases A to B ____________________

Phases A to C ____________________

Phases B to C ____________________

Phase A to ground ________________

Phase B to ground ________________

Phase C to ground ________________

K. Deenergize 240-volt power supply

L. Deenergize transformer bank, and connect midpoint of T1 secondary to ground

M. Reenergize transformer bank

N. Again check and record voltages between each secondary-phase lead and ground

Phase A to ground ________________

Phase B to ground ________________

Phase C to ground ________________

(NOTE: Voltages to ground are stable and high leg registers on voltmeter.)

O. Deenergize transformer bank

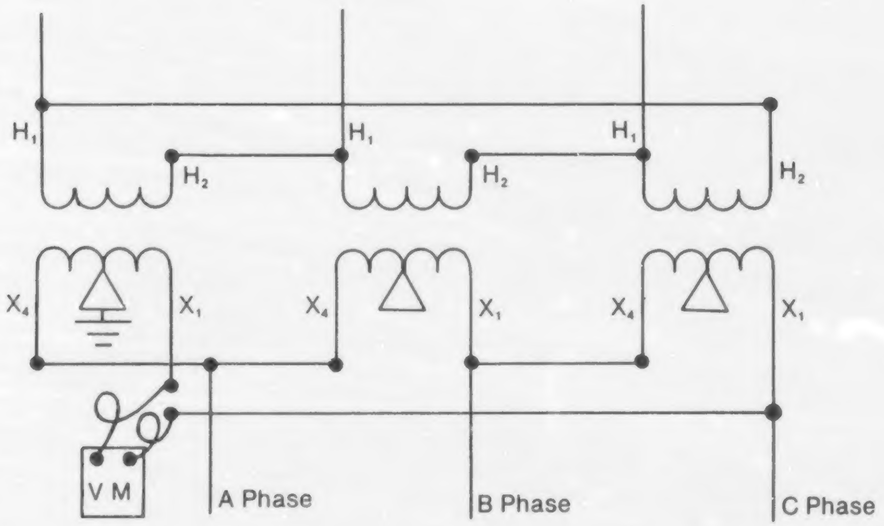
P. Disconnect T1 leads X1 and X4

JOB SHEET #1

Q. Connect T1 lead X4 to T2 lead X4 (Figure 12)

(CAUTION: Tie or otherwise fasten T1 lead X1 clear of other leads and ground. Be cautious of higher voltages.)

FIGURE 12


H₁
H₂
H₁
H₂
H₁
H₂
X₄
X₁
X₄
X₁
X₄
X₁
V M
A Phase
B Phase
C Phase

R. Reenergize transformer bank

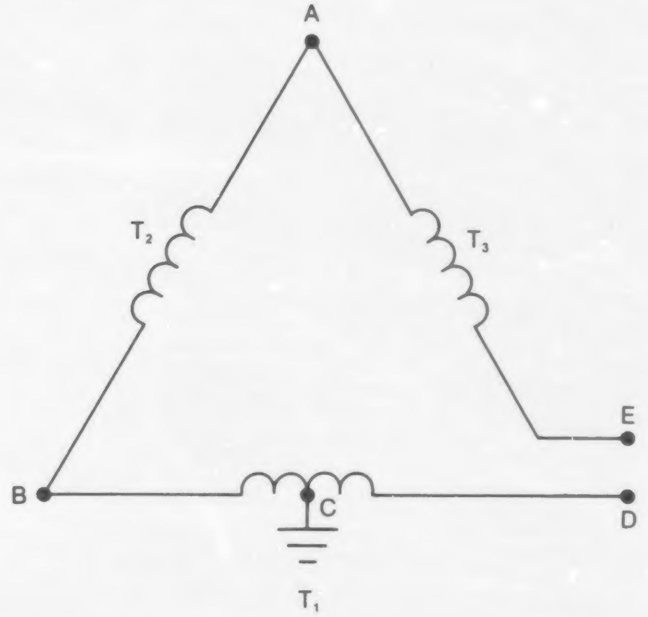
S. Set voltmeter on 600-volt scale

JOB SHEET #1

T. Check and record voltages between various points on the secondary shown in Figure 13

(NOTE: This experiment shows what can happen if transformer polarities are not taken into consideration when connecting transformers.)

FIGURE 13



Points A to C ____________________

Points B to C ____________________

Points C to D ____________________

Points B to C ____________________

Points B to E ____________________

Points D to E ____________________

Points A to E ____________________

Points B to D ____________________

U. Open and lock open 240-volt power supply switch

(CAUTION: When working with voltages of 4,160; 7,200; 12,500 or higher; the results are magnified accordingly.)

(NOTE: Show work to instructor for evaluation and comments; if approved by instructor, transformers may be held for Job Sheet #2; if not approved, rework to the instructor's satisfaction.)

IN-PLANT DISTRIBUTION SYSTEMS
UNIT I

JOB SHEET #2 — CONNECT TRANSFORMER PRIMARY AND SECONDARY WINDINGS IN A DELTA-WYE CONFIGURATION

I. Equipment and materials

A. Three-phase power supply, 240-volt

(NOTE: A three-phase 208-volt power supply will also serve satisfactorily.)

B. Three 5-ampere fuses in 240-volt circuit

C. #14 wire, approximately 20 feet

D. Wire nuts or bolts for connections

E. Three transformers rated 240 to 120/240 (200 volt-amperes to 1 kilovolt-ampere capacity)

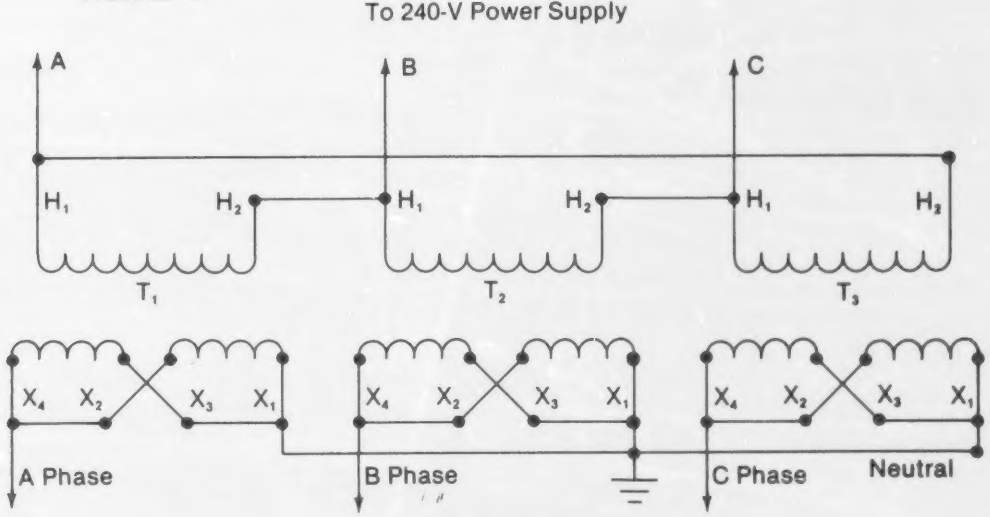
F. Voltmeter with 600-volt scale

G. One lamp and socket, 100 watt, 120 volt

II. Procedure

A. Connect transformers in a delta primary to wye secondary configuration as shown in Figure 14

FIGURE 14


To 240-V Power Supply
A
B
C
H_1
H_2
H_1
H_2
H_1
H_2
T_1
T_2
T_3
X_4
X_2
X_3
X_1
X_4
X_2
X_3
X_1
X_4
X_2
X_3
X_1
A Phase
B Phase
C Phase
Neutral

JOB SHEET #2

B. Double-check all connections for correctness

(NOTE: Show connections to instructor before proceeding.)

C. Energize 240-volt circuit

D. Read and record low-side voltages

Phases A to B ____________________

Phases A to C ____________________

Phases B to C ____________________

Phase A to neutral ____________________

Phase B to neutral ____________________

Phase C to neutral ____________________

E. Deenergize 240-volt circuit

F. Connect 100-watt lamp to phase A and neutral

G. Reenergize 240-volt circuit

H. Read and record voltages

Phase A to neutral ____________________

Phase B to neutral____________________

Phase C to neutral____________________

I. Deenergize 240-volt circuit

J. Connect the neutral to ground

(NOTE: An ungrounded neutral can shift when the load is unbalanced, causing low voltage at one point and high voltage at other points.)

K. Read and record low-side voltages again

Phase A to neutral ____________________

Phase B to neutral ____________________

Phase C to neutral ____________________

Phases A to B ____________________

Phases A to C ____________________

Phases B to C ____________________

JOB SHEET #2

L. Deenergize 240-volt circuit

M. Disconnect T1 secondary leads from T2 and T3

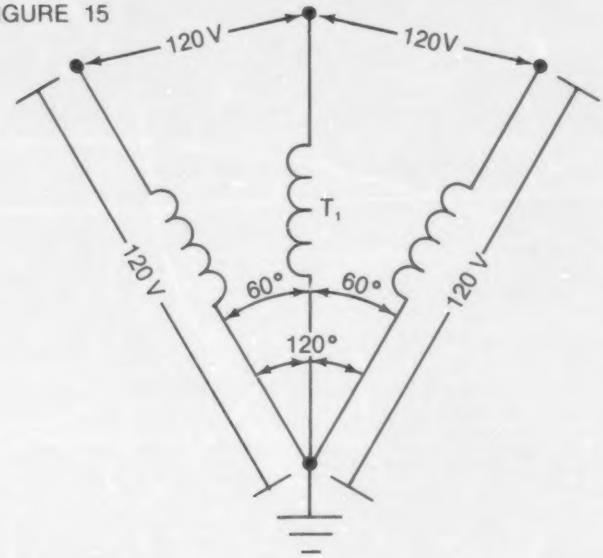
N. Connect terminal X4 of T1 to the neutral point

O. Reenergize the circuit

P. Read and record secondary voltages

(NOTE: Figure 15 represents shift of phases due to improper connections.)

FIGURE 15



Phases A to B ____________________

Phases A to C ____________________

Phases B to C ____________________

Phase A to neutral ____________________

Phase B to neutral ____________________

Phase C to neutral ____________________

(NOTE: Show work to instructor for evalution and comments.)

Q. Disassemble transformer

R. Clean work area; put away all equipment and materials

IN-PLANT DISTRIBUTION SYSTEMS
UNIT I

TEST

NAME ____ SCORE ________________

1. Match to their correct definitions terms associated with in-plant distribution systems.

______a. Connected to earth or to some conducting body that serves in place of earth

______b. Method of making transformer connections to obtain desired voltage

______c. Interior and exterior wiring that extends from load end of service drop; includes all associated hardware, fittings, and wiring devices

______d. Ability to hold a set voltage within a set tolerance

______e. Ratio of true power (watts) to apparent power (volt-amperes)

______f. Device used to shift phase of inductive load

1. Voltage system
2. In-plant power distribution system (premises wiring system)
3. Grounded
4. Capacitor
5. Power factor
6. Voltage regulation

2. State items to consider when planning an in-plant distribution system.

a. ____

b. ____

c. ____

d. ____

e. ____

f. ____

g. ____

h. ____

TEST

3. Name the most commonly used in-plant voltage systems.

a. ____

____

b. ____

____

c. ____

____

4. Distinguish between advantages and disadvantages of commonly used voltage systems. Write an "A" in the blanks before advantages and a "D" in the blanks before disadvantages.

Single-phase AC three wire

______a. Limits plant to single-phase motors

______b. May be expensive to expand

______c. Is simple to maintain

______d. Is easy to overload

______e. Requires less expensive distribution equipment

______f. Contains fewer fault currents than other systems

Three-phase wye

______a. Is flexible

______b. Requires neutral to be firmly grounded

______c. Has good voltage regulation

______d. May contain excessive fault currents

______e. Uses economical motors

______f. Is easy to balance system load

______g. Contains minimum variety in size of wire and conduit

TEST

______h. Provides simple and effective means of suppressing damaging transient line-to-ground overvoltages

______i. May use all three phases for 120-volt circuits

______j. Some equipment must be special ordered for 208-volt

Three-phase delta

______a. Does not require grounding

______b. Is less flexible than other systems

______c. Has good voltage regulation

______d. Is difficult to balance system load

______e. Can be operated on open delta at reduced load if transformer fails

______f. Has wild or high leg if midpoint of one transformer is grounded

______g. Uses economical motors

5. State general uses of the open-delta system.

a. ____

____

b. ____

____

6. Name principal uses of direct-current power in a plant.

a. ____

b. ____

7. Select from the following list safety measures to be used with systems over 600 volts. Write an "X" in the blank before each correct answer.

______a. *Do not* open under load any expulsion-type cutouts or fuse links

______b. Open cutouts and fuse links before disconnecting load

______c. Ground each phase before handling conductors or equipment

______d. Provide greater working clearances than for lower-voltage systems

TEST

______e. Be careful not to ground phases when handling conductors

______f. Test all phases for voltage (phase-to-phase and phase-to-ground) before starting any work

______g. Handle 600-volt systems the same as 480-volt systems

8. State reasons for using capacitors.

    a. ____

    b. ____

    c. ____

9. State rules for wye-system voltages and currents.

    a. ____

    b. ____

    c. ____

    d. ____

10. State rules for delta-system voltages and currents.

    a. ____

    b. ____

    c. ____

    d. ____

(NOTE: Test questions 11 and 12 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

11. Sketch transformer connections for in-plant voltage distribution systems.

12. Demonstrate the ability to

    a. Connect three transformers in a delta-delta configuration.

    b. Connect transformer primary and secondary windings in a delta-wye configuration.

IN-PLANT DISTRIBUTION SYSTEMS
UNIT I

ANSWERS TO TEST

1.

a.	3	d.	6
b.	1	e.	5
c.	2	f.	4

2. a. Service dependability
   b. Flexibility
   c. Voltage regulation
   d. Allowance for growth
   e. Safety
   f. Efficiency
   g. Initial costs
   h. Operating and maintenance costs

3. a. Single-phase AC three wire
   b. Three-phase wye with neutral grounded
   c. Three-phase delta

4.

Single-phase AC three wire		**Three-phase wye**		**Three-phase delta**	
a.	D	a.	A	a.	A
b.	D	b.	D	b.	D
c.	A	c.	A	c.	A
d.	D	d.	D	d.	D
e.	A	e.	A	e.	A
f.	A	f.	A	f.	D
		g.	A	g.	A
		h.	A		
		i.	A		
		j.	D		

ANSWERS TO TEST

5. a. Serving a predominantly single-phase load, possibly with one three-phase motor
   b. Restoring reduced power to a three-phase system when a transformer fails

6. a. Motors
   b. Control circuits

7. a, c, d, f

8. a. To improve power factor
   b. To reduce electricity costs
   c. To reduce system load amperes

9. a. Line voltage equals coil voltage times 1.73
   b. Phase voltage equals line voltage divided by 1.73
   c. Line current equals coil current
   d. Total circuit current equals line amperes times 1.73

10. a. Line current equals coil current times 1.73
    b. Coil current equals line current divided by 1.73
    c. Line voltage equals coil voltage
    d. Total circuit current equals line amperes times 1.73

11. Evaluated to the satisfaction of the instructor

12. Performance skills evaluated to the satisfaction of the instructor

IN-PLANT DISTRIBUTION EQUIPMENT
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to identify major components of in-plant distribution equipment, test transformers for turn ratios and insulation resistance, and calculate power factor. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with in-plant distribution equipment.
2. Write meanings of abbreviations and symbols associated with in-plant distribution equipment.
3. State the maintenance electrician's motto.
4. Distinguish between indoor and outdoor electrical distribution equipment.
5. Name types of service-entrance conductors.
6. Explain reasons for using stress cones.
7. Match different types of transformers to their general uses.
8. Identify components of an electrical equipment grounding system.
9. Identify points of delta and wye electrical system grounding.
10. Calculate power factor for a single-phase alternating-current circuit.
11. Distinguish between feeder and branch circuits.
12. Match meters to their proper switchboard connections.
13. Draw proper meter connections.
14. Demonstrate the ability to
    a. Test transformer turn ratios.
    b. Test transformer insulation resistance.
    c. Calculate power factor, and install capacitor to improve power factor.

IN-PLANT DISTRIBUTION EQUIPMENT
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order materials to supplement unit.

1. *American Electrician's Handbook*

(NOTE: Obtain one or more copies of the current edition for the class library. Order from McGraw-Hill Book Company, 1221 Avenue of the Americas, New York, New York 10036.)

2. *National Electrical Code*

(NOTE: Obtain several copies of the current edition from the National Fire Protection Association, 470 Atlantic Avenue, Boston, Massachusetts 02210. Copies may also be obtained from most city halls.)

3. *Westinghouse—Electrical Maintenance Hints*

(NOTE: Obtain one or more copies of the current edition for the class library. Order from WESCO [Westinghouse Electric Supply Company], Westinghouse Building, Gateway Center, Pittsburgh, Pennsylvania 15222.)

B. Make transparencies.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information, assignment, and job sheets.

F. Discuss information, assignment, and job sheets.

1. Discuss transmission and distribution systems, using Information Sheet, Section I. Remember that your school provides the perfect place to show typical transmission and distribution panels as they are used in a typical industrial or commercial setting. Assignment Sheet #1 reinforces information given in this section.

2. Discuss abbreviations and symbols, using Information Sheet, Section II and an actual transformer and motor from the shop. Show students the marking of the leads related to the abbreviations and symbols. Assignment Sheet #2 reinforces and provides review of information given in this section.

SUGGESTED ACTIVITIES

3. Discuss the maintenance electrician's motto, using Information Sheet, Section III. Remind students that it is not only necessary to see that work is done according to the *Code* and that it functions properly, but that there are safety and maintenance factors to consider. Stress the importance of neatness when doing maintenance.

4. Discuss distribution equipment, using Information Sheet, Section IV. Contact the local power company and request a tour of its substation, or tour a local industrial building. Point out the different types of distribution equipment, and possibly have one of the local power company representatives give a short talk on the use of distribution equipment.

5. Discuss service entrance conductors, using Information Sheet, Section V. Tour the local supply house so that students may see examples of the different types of service entrance conductors.

6. Use Information Sheet, Section VI to discuss reasons for using stress cones. Most local power companies have the tools, equipment, and labor necessary to install stress cones. Ask the local power company to demonstrate the use of stress cones. Usually, they will be more than happy to set up a demonstration in your own shop.

7. Discuss types of transformers and their uses, using Information Sheet, Section VII. Use the *Code* to find allowable uses for different types of transformers. Point out and discuss the exceptions listed in the *Code*. Tour your school campus to show students control and main-power transformers.

8. Discuss components of electrical equipment grounding systems, using Information Sheet, Section VIII. Remember that your school shop and campus provide students with examples of proper grounding and the equipment associated with grounding electrical systems.

9. Discuss points of delta and wye electrical system grounding, using Information Sheet, Section IX. Use the *Code* to stress the importance of the components and their typical makeups for the grounding system. Show students possible grounding places in the shop, such as ground rods and water pipes.

10. Explain how to calculate power factor, using Information Sheet, Section X, and Job Sheet #3. Review inductance and capacitance, reminding students that inductance has a lagging power factor and capacitance has a leading power factor. Discuss the use of capacitors to correct power factor problems in a main plant.

SUGGESTED ACTIVITIES

11. Discuss feeder and branch circuits, using Information Sheet, Section XI, and Transparency #1. Use your shop electrical system to explain typical branch and feeder circuit arrangements.

12. Discuss meters and their proper connections, using Information Sheet, Section XII and Transparencies #2 through #5, as well as Assignment Sheet #3. Job Sheets #1 and #2 allow you to demonstrate the proper connections for most meters used in industry. Stress to students the necessity of the proper connection of meters to protect the meter itself and to obtain proper readings from the meters.

G. Give test.

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Feeder and Branch Circuits
2. TM #2 — Meter Connections
3. TM #3 — High-Voltage Potential Transformer Connections for Voltmeter
4. TM #4 — High-Current and High-Voltage Current Transformer Connections
5. TM #5 — High-Current and High-Voltage Wattmeter Connections

E. Assignment sheets

1. Assignment Sheet #1 — Identify Components of an Electrical Equipment Grounding System
2. Assignment Sheet #2 — Interpret Abbreviations and Symbols Associated with In-Plant Distribution Equipment
3. Assignment Sheet #3 — Draw Proper Meter Connections

F. Answers to assignment sheets

SUGGESTED ACTIVITIES

G. Job sheets

   1. Job Sheet #1 — Test Transformer Turn Ratios

   2. Job Sheet #2 — Test Transformer Insulation Resistance

   3. Job Sheet #3 — Calculate Power Factor, and Install Capacitor to Improve Power Factor

H. Test

I. Answers to test

III. Unit references

A. Adams, James E. *Electrical Principles and Practices,* 2nd ed. New York: McGraw-Hill Book Company, 1973.

B. *Amprobe Instrument Test Equipment Catalog AAD-38-1, Part 1.* Lynbrook, New York: Amprobe Instrument, Division of Core Industries Inc., 1982.

C. Croft, Terrell, et al. *American Electrician's Handbook,* 9th ed. New York: McGraw-Hill Book Company, 1970.

D. Graham, Kennard C. *Industrial and Commercial Wiring,* 2nd ed. Alsip, Illinois: American Technical Publishers, Inc., 1963.

E. Hubert, Charles I. *Preventive Maintenance of Electrical Equipment,* 2nd ed. New York: McGraw-Hill Book Company, 1969.

F. Lister, Eugene C. *Electric Circuits and Machines,* 6th ed. New York: McGraw-Hill Book Company, 1984.

G. *National Electrical Code.* Boston, Massachusetts: National Fire Protection Association, 1981.

H. *Square D Company Digest 1982.* Milwaukee, Wisconsin: Square D Company, April, 1982.

I. *Westinghouse—Electrical Maintenance Hints.* Trafford, Pennsylvania: Westinghouse Electrical Corporation, Printing Division, 1974.

IN-PLANT DISTRIBUTION EQUIPMENT
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Ground — To connect electrical equipment either intentionally or accidentally to the earth or to some conducting body that serves as the earth

B. Grounded — Connected to earth or to some conducting body that serves in place of the earth

C. Grounded conductor — System or circuit conductor that is intentionally grounded

D. Equipment grounding conductor — Conductor used to connect non-current-carrying metal parts of equipment to the system-grounded conductor or grounding-electrode conductor

E. Grounding-electrode conductor — Conductor used to connect grounding electrode to the equipment grounding conductor or to grounding conductor of circuit at service equipment or at source of separately derived system

F. Service equipment — Conductors and equipment for receiving energy from electrical supply system to the premises wiring

G. Service conductors — Supply conductors that extend from transformers to the service equipment

H. Feeder — All circuit conductors between service equipment or generator switchboard of an isolated plant and final branch-circuit overcurrent device

I. Branch circuit — Circuit conductors between final overcurrent device protecting circuit and the outlet

J. Power factor — Ratio of true power (watts) to apparent power (volts times amperes) of an alternating-current circuit or system

K. Corona — Electrical discharge on surface of high-voltage equipment producing free oxygen ions (ozone)

L. Stress cone — Device that provides ozone-resistant insulation at the termination of shielding on a high-voltage conductor

M. Bonding — Connecting metallic parts to assure electrical continuity with capacity to conduct any current likely to be imposed

N. Bonding jumper — A reliable conductor to assure the required electrical conductivity between metal parts required to be electrically connected

INFORMATION SHEET

O. Circuit bonding jumper — Connection between portions of a conductor in a circuit to maintain required ampacity

P. Equipment bonding jumper — Connection between two or more portions of equipment grounding conductor

Q. Main bonding jumper — Connection between grounded circuit conductor and equipment grounding conductor at the service

II. Typical abbreviations and symbols associated with in-plant distribution equipment (Assignment Sheet #2)

A. HV — High voltage

B. LV — Low voltage

C. ϕ — Phase

D. hp — Horsepower

E. Pf — Power factor

F. H1, H2 . . . — Primary leads

G. X1, X2 . . . — Secondary leads

H. *NEC — National Electrical Code*

I. ⏚ — Ground

III. Maintenance electrician's motto

A. Keep it clean

B. Keep it dry

C. Keep it tight

D. Keep it cool

E. Keep it simple

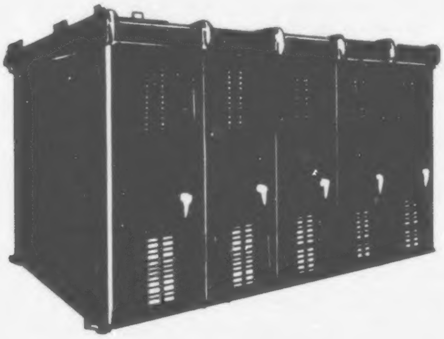
INFORMATION SHEET

IV. Indoor and outdoor electrical distribution equipment

A. Outdoor distribution equipment (Figure 1)

(NOTE: Outdoor distribution equipment is oil-filled and weatherproof.)

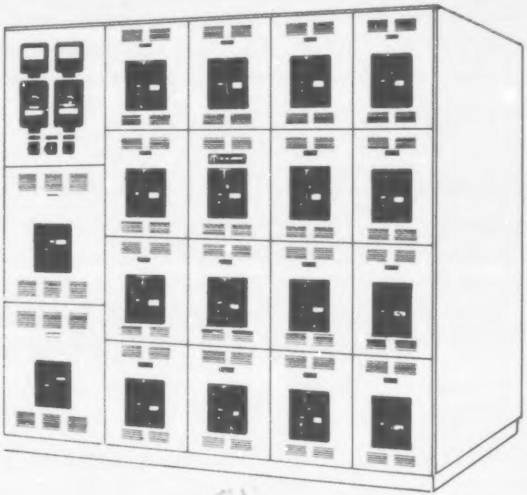
FIGURE 1



B. Indoor distribution equipment (Figure 2)

(NOTE: Indoor distribution equipment is not oil-filled or weatherproof. The meters and switch handles are exposed.)

FIGURE 2



INFORMATION SHEET

V. Types of service-entrance conductors

A. Thermoplastic insulated

EXAMPLES: THW — Moisture- and heat-resistant thermoplastic
THWN — Nylon-jacketed, moisture- and heat-resistant thermoplastic
THHN — Flame retardant, heat resistant

(NOTE: Article 310-13 of the *NEC* gives a full list of conductor insulations.)

B. Shielded cable

EXAMPLES: Butyl rubber insulation
Paper
Varnish cambric

(NOTE: Terminations for medium-voltage cables involve considerations other than good connection of the conductors.)

C. Copper or aluminum busbar with heavy, bolted connections

(NOTE: Busbars are generally enclosed in metal housings to protect them from weather and unauthorized personnel.)

D. Polyethylene

INFORMATION SHEET

VI. Reasons for using stress cones (Figure 3)

(NOTE: Stress-cone kits are available from several manufacturers of electrical equipment.)

A. To prevent entrance of moisture and to avoid giving rise to corona

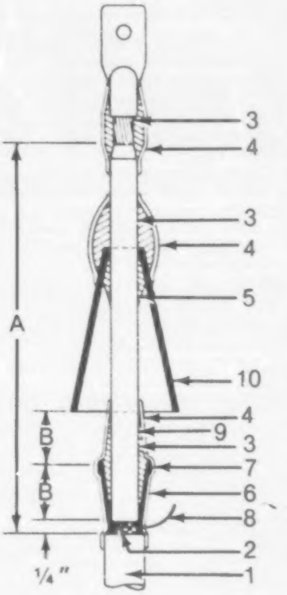
B. To relieve the concentration of voltage stress and corona at point where shielding ends

C. To prevent premature cable failure

(NOTE: Either high-voltage stress or corona formation at the point of shielding end can be responsible for premature cable failure.)

EXAMPLE:

FIGURE 3



A—Minimum Length
B—Stress-Cone Length
1—Jacket
2—Cable Shielding
3—Insulating Tape
4—Anhydrous Tape—Cable Paint
5—Friction Tape
6—Tinsel Shielding Braid
7—Binding Wire
8—Ground Wire
9—Stress Cone—Thickness, Same as Cable Insulation
10—Rain Shield

Conductor Size, AWG or MCM	Length of A and B (Inches)					
	5,000 Volts		7,500 Volts		15,000 Volts	
	A	B	A	B	A	B
8-1,000	14	2	17	2.5	24	3.5

Source: Rome Cable Corporation.

INFORMATION SHEET

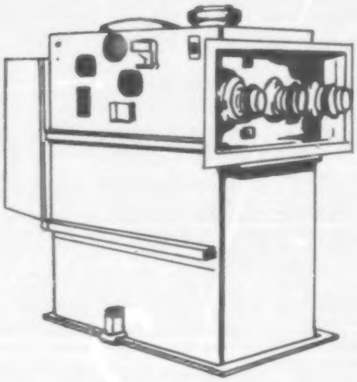
VII. Types of transformers and their general uses (Figures 4-9)

A. Oil-filled — Used only in outdoor locations due to fire hazards

(NOTE: Only under certain conditions listed in the *NEC,* Article 450-26, is indoor installation permitted.)

EXAMPLE:

FIGURE 4

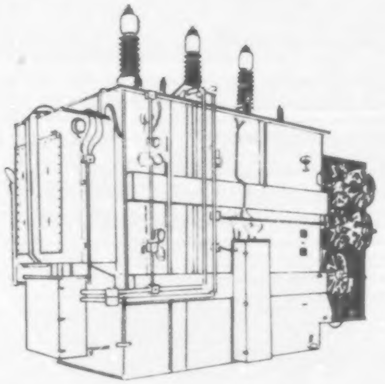


Adapted with permission of the Square D Company.

B. Air-cooled dry-type — Used indoors, usually in the interior of large plants, or used outdoors with weatherproof housing

EXAMPLE:

FIGURE 5



Used with permission of Westinghouse Electric Corporation.

INFORMATION SHEET

C. Compound-filled dry-type — Used to feed 120-volt receptacles where the system voltage is high

EXAMPLES:

FIGURE 6

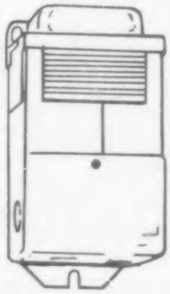
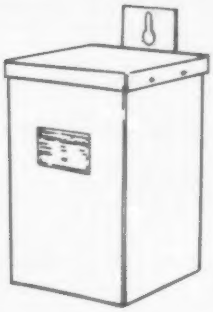


FIGURE 7



INFORMATION SHEET

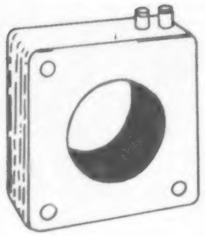
D. Instrument transformers

1. Current transformer — Used for metering and relay protection

   (NOTE: Always keep current transformer secondary shorted except when reading ammeter or wattmeter. Never let energized current transformer secondary become open because of possible high voltage.)

   EXAMPLE:

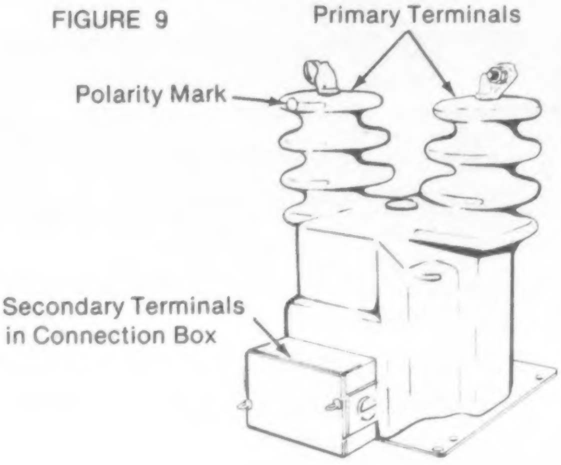
FIGURE 8



2. Potential transformer — Used for metering and relaying

   EXAMPLE:

FIGURE 9


Primary Terminals
Polarity Mark
Secondary Terminals in Connection Box

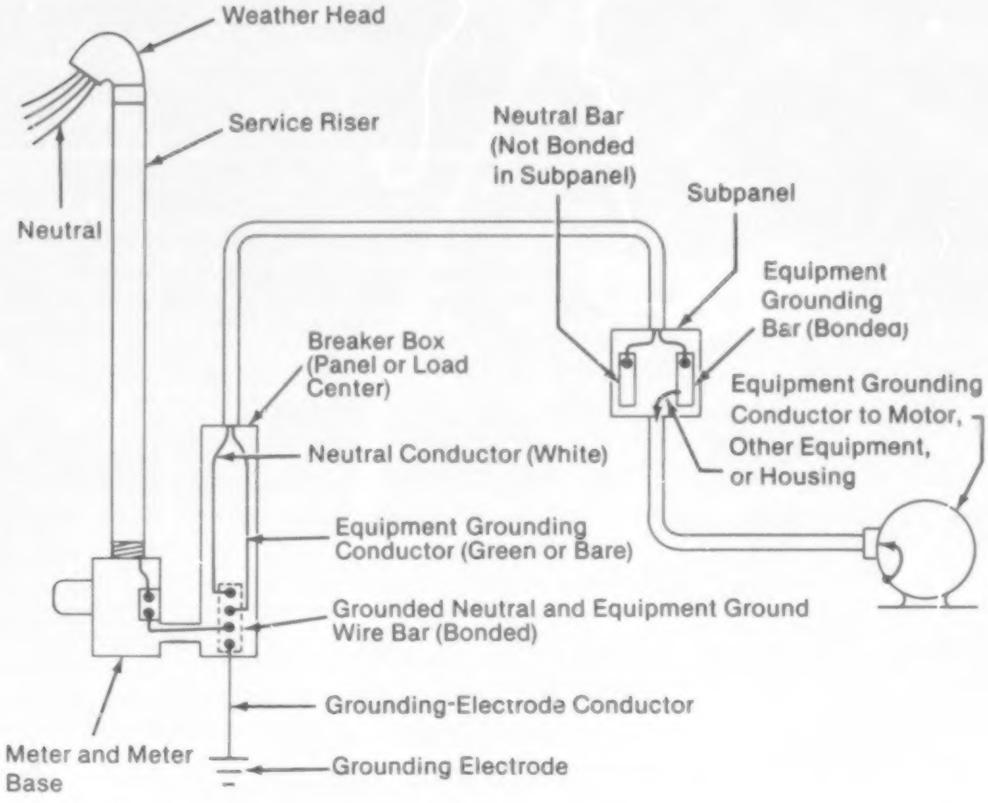
Used with permission of Westinghouse Electric Corporation.

INFORMATION SHEET

VIII. Components of an electrical equipment grounding system (Figure 10; Assignment Sheet #1)

(NOTE: Some power companies require the grounding-electrode conductor to terminate in the meter base. Always check with local authority for proper termination.)

FIGURE 10

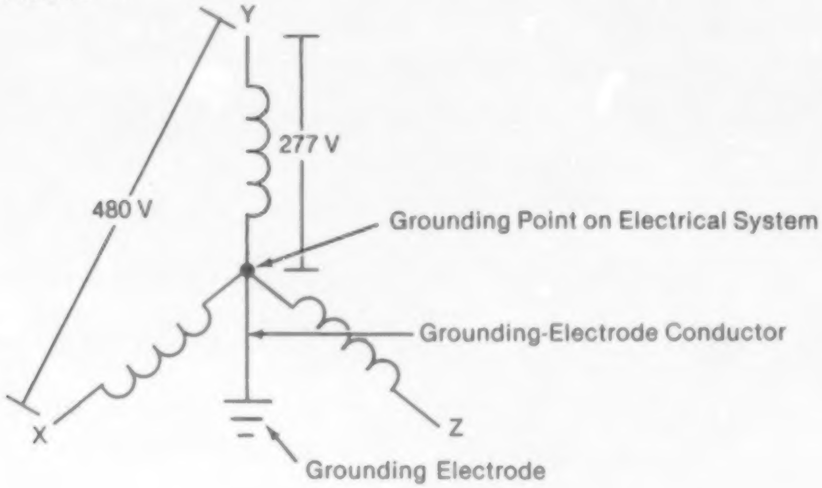

Weather Head
Service Riser
Neutral
Neutral Bar (Not Bonded in Subpanel)
Subpanel
Equipment Grounding Bar (Bonded)
Breaker Box (Panel or Load Center)
Equipment Grounding Conductor to Motor, Other Equipment, or Housing
Neutral Conductor (White)
Equipment Grounding Conductor (Green or Bare)
Grounded Neutral and Equipment Ground Wire Bar (Bonded)
Grounding-Electrode Conductor
Meter and Meter Base
Grounding Electrode

INFORMATION SHEET

IX. Points of delta and wye electrical system grounding (Figures 11 and 12)

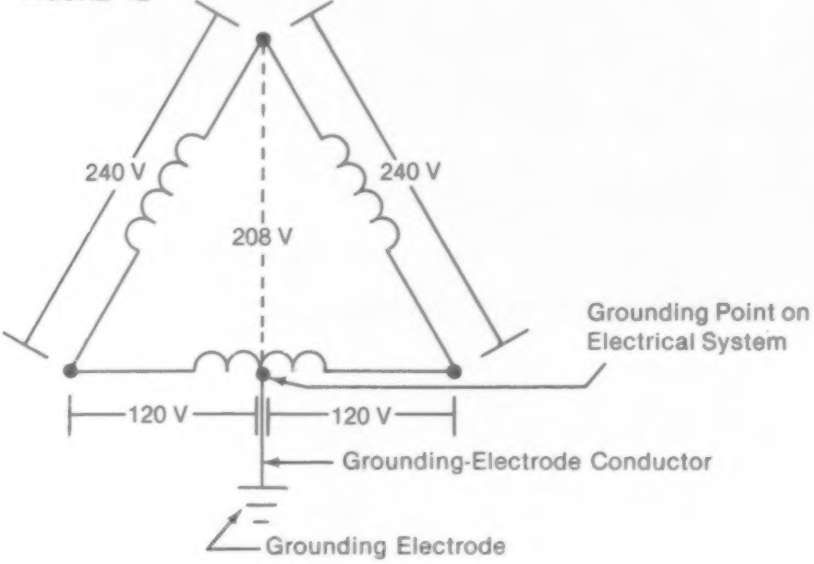
A. 277/480-volt wye system grounding

FIGURE 11


Y
277 V
480 V
Grounding Point on Electrical System
Grounding-Electrode Conductor
X
Z
Grounding Electrode

B. 120/240-volt delta system grounding

FIGURE 12


240 V
240 V
208 V
Grounding Point on Electrical System
120 V
120 V
Grounding-Electrode Conductor
Grounding Electrode

INFORMATION SHEET

X. Calculating power factor of a single-phase alternating-current circuit

- A. Divide apparent power (volts times amperes) by true power (watts)
- B. Use the formula $Pf = \frac{W}{V \times A}$

EXAMPLE: Where

Watts = 750
Volts = 120
Amperes = 8

$$Pf = \frac{W}{V \times A}$$
$$= \frac{750}{120 \times 8}$$
$$= \frac{750}{960}$$
$$= 0.78 \text{ or } 78\%$$

XI. Difference between feeder and branch circuits (Transparency #1)

- A. Feeder circuit — Consists of all circuit conductors between the service equipment, or generator switchboard of an isolated plant, and the final branch-circuit overcurrent device
- B. Branch circuit — Consists of circuit conductors between final overcurrent device protecting the circuit and the outlet(s)

XII. Meters and their proper switchboard connections (Transparencies #2-#5; Assignment Sheet #3)

- A. Voltmeter — Connects across the line

  (NOTE: To reduce the voltage to a safe value, high voltages are read by use of a potential transformer [Transparency #3]. Generally, switchboard instrument connections are made to drum or selector switches so that one meter is used for measuring the current or voltage of all three phases.)

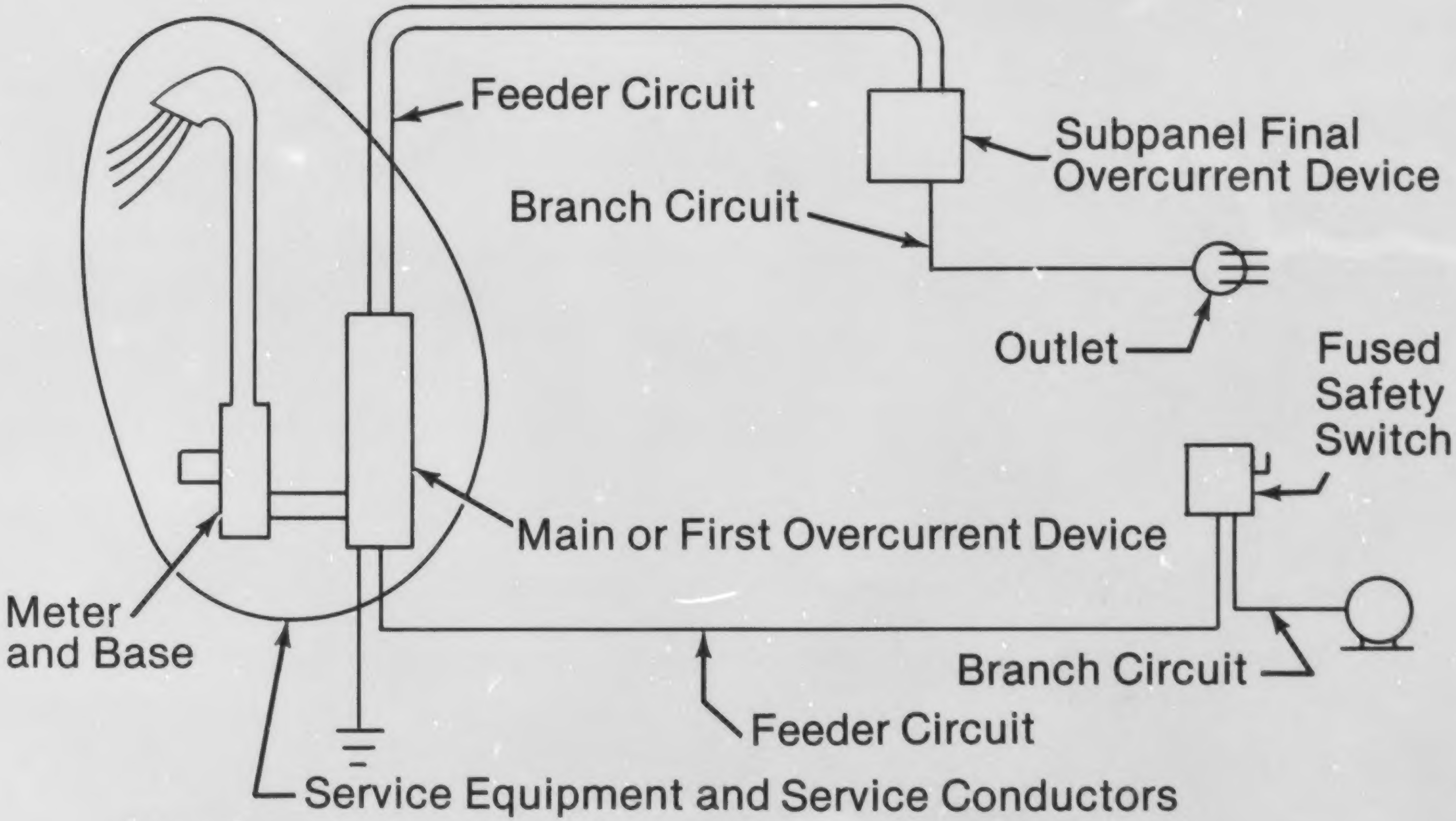
- B. Ammeter — Connects in series with the line

  (NOTE: High current and high-voltage currents are obtained by using current transformers [Transparency #4].)

- C. Wattmeter — Connects across the line for potential and in series for current

  (NOTE: High-voltage circuits make both potential and current transformers necessary to measure the power flowing in the circuit [Transparency #5]. Polyphase circuits require multiple transformers, both current and potential.)

Feeder and Branch Circuit



Feeder Circuit

Subpanel Final
Overcurrent Device

Branch Circuit

Outlet

Fused
Safety
Switch

Main or First Overcurrent Device

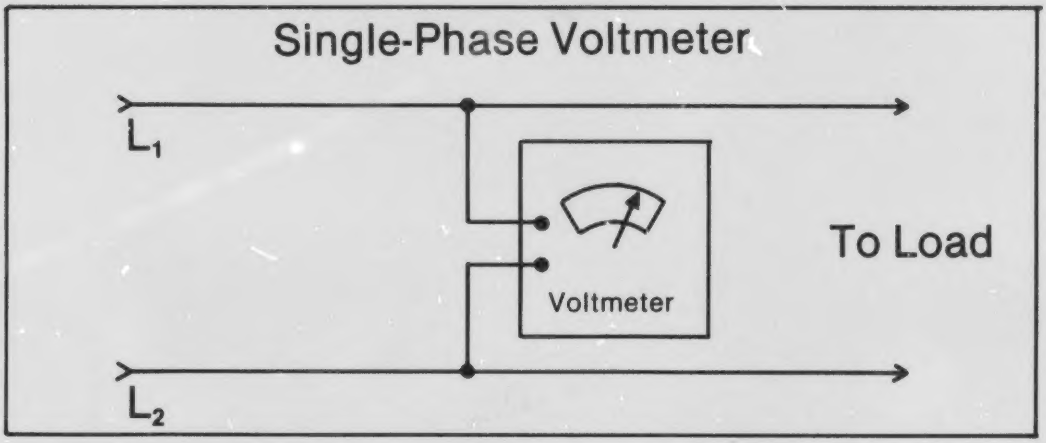
Meter
and Base

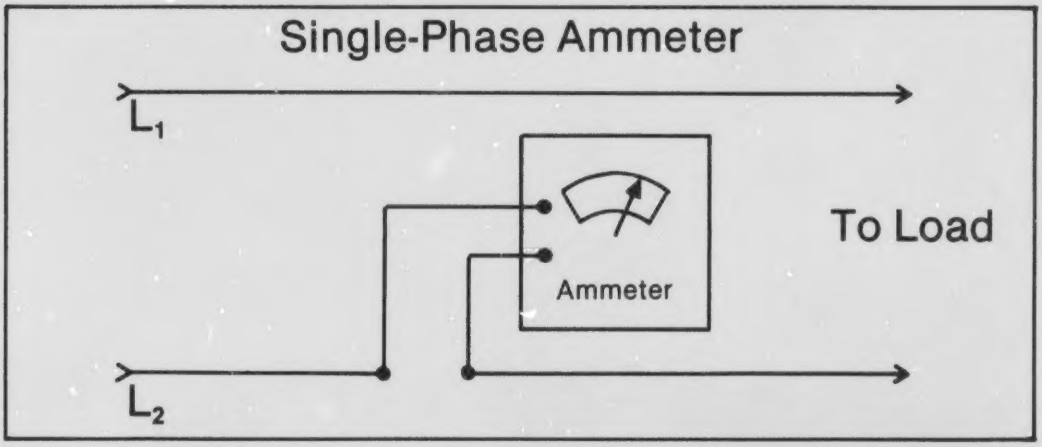
Branch Circuit

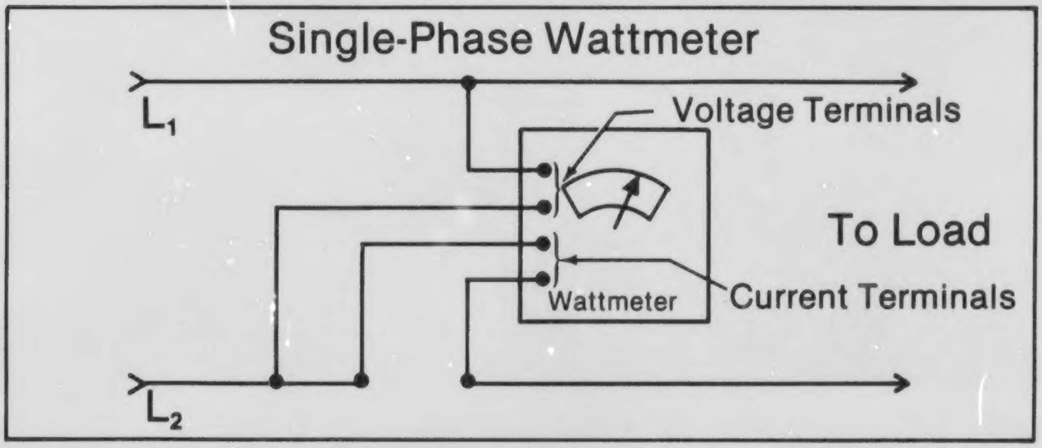
Feeder Circuit

Service Equipment and Service Conductors

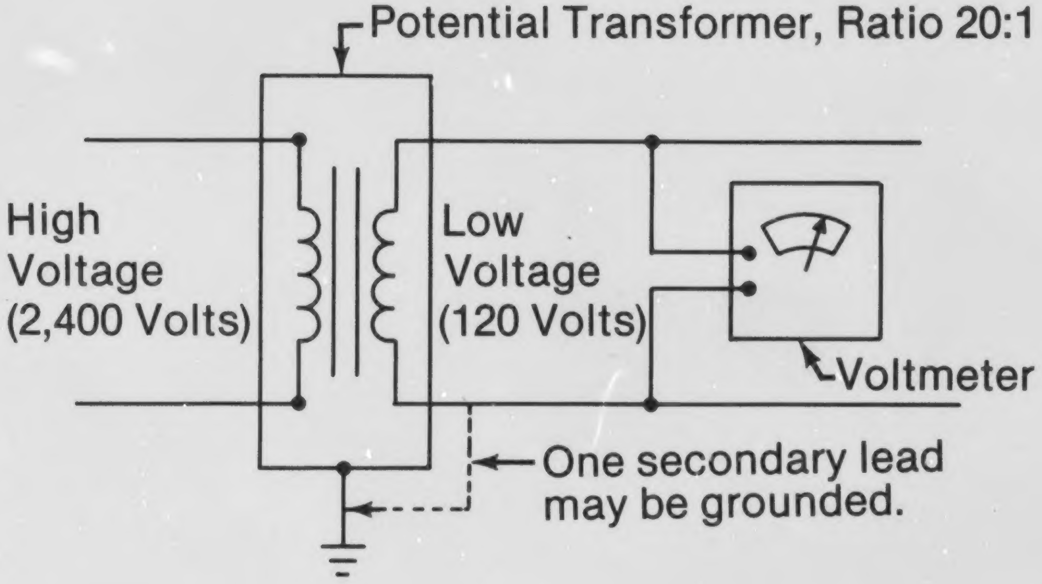
Meter Connections


Single-Phase Voltmeter
L1
L2
Voltmeter
To Load


Single-Phase Ammeter
L1
L2
Ammeter
To Load

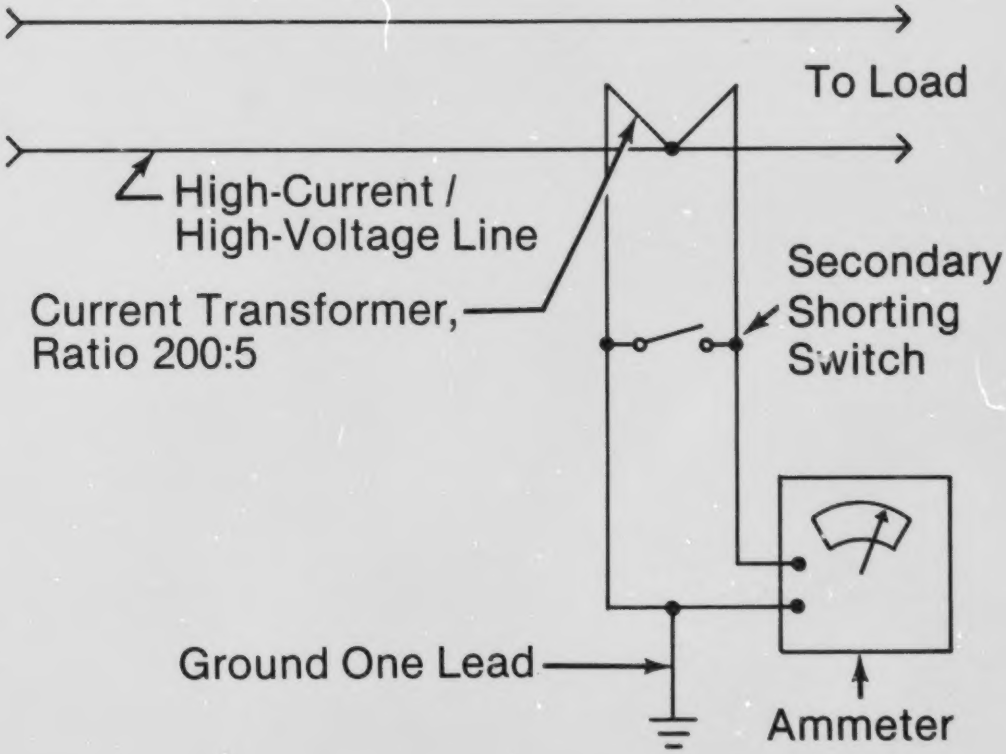

Single-Phase Wattmeter
L1
L2
Voltage Terminals
Wattmeter
To Load
Current Terminals

High-Voltage Potential Transformer Connections for Voltmeter


Potential Transformer, Ratio 20:1
High Voltage (2,400 Volts)
Low Voltage (120 Volts)
Voltmeter
One secondary lead may be grounded.

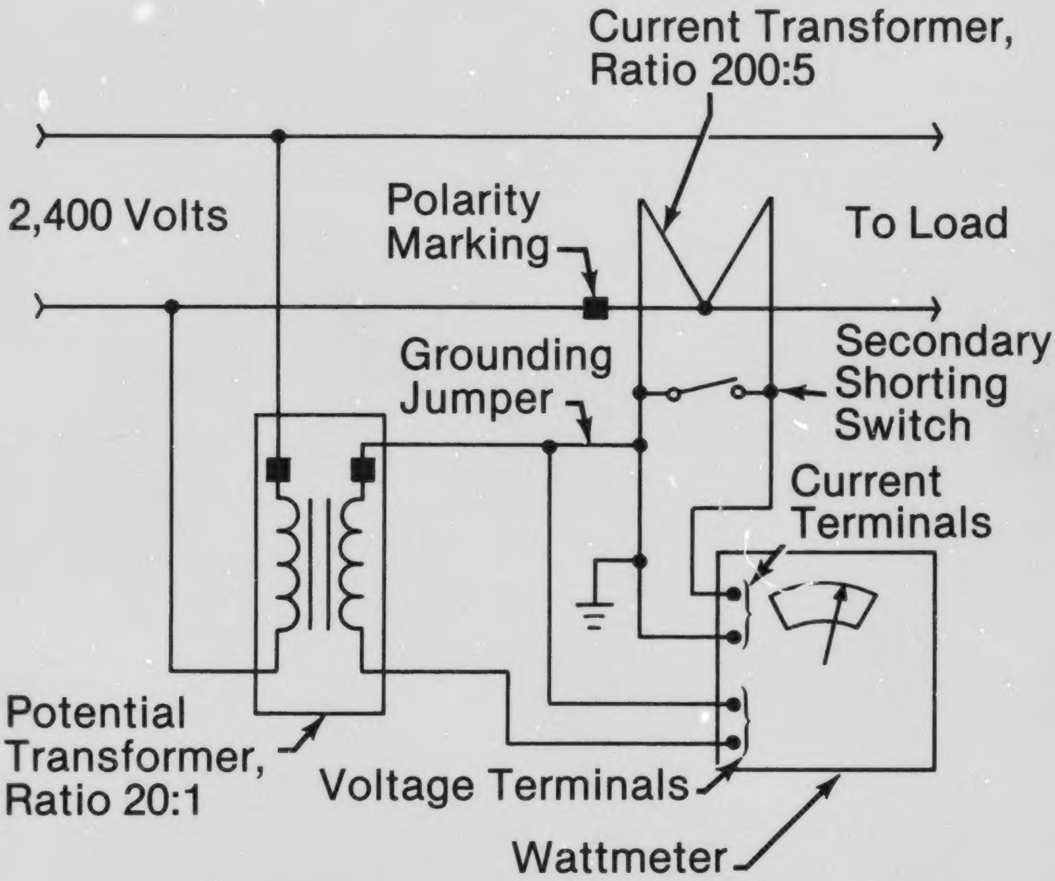
To find true voltage, reduce the potential transformer if necessary, and then multiply the scale reading by the ratio of the potential transformer.

High-Current and High-Voltage Current Transformer Connections


To Load
High-Current /
High-Voltage Line
Current Transformer,
Ratio 200:5
Secondary
Shorting
Switch
Ground One Lead
Ammeter

To find true current, reduce the current transformer ratio if necessary, and then multiply the scale reading by the ratio of the current transformer (True Current = Scale Reading × 40:1).

High-Current and High-Voltage Wattmeter Connections


Current Transformer, Ratio 200:5
2,400 Volts
Polarity Marking
To Load
Grounding Jumper
Secondary Shorting Switch
Current Terminals
Potential Transformer, Ratio 20:1
Voltage Terminals
Wattmeter

To find true wattage, reduce the current transformer ratio if necessary, and then multiply the scale reading by the product of the current and potential transformer ratios (True Wattage = Scale Reading × [40:1 × 20:1]).

IN-PLANT DISTRIBUTION EQUIPMENT
UNIT II

ASSIGNMENT SHEET #1 — IDENTIFY COMPONENTS OF AN ELECTRICAL EQUIPMENT GROUNDING SYSTEM

NAME ________________________________ SCORE ______________

The industrial electrician must be able to identify the components of a grounding system in order to adhere to the specifications set forth in the *National Electrical Code.*

Identify the components of the electrical grounding system on the following page. Write the correct names in the blanks.

Weather head

Service riser

Neutral

Meter and meter base

Equipment grounding conductor (green or bare)

Neutral conductor (white)

Neutral bar (not bonded in subpanel)

Breaker box (panel or load center)

Grounded neutral and equipment ground wire bar (bonded)

Grounding-electrode conductor

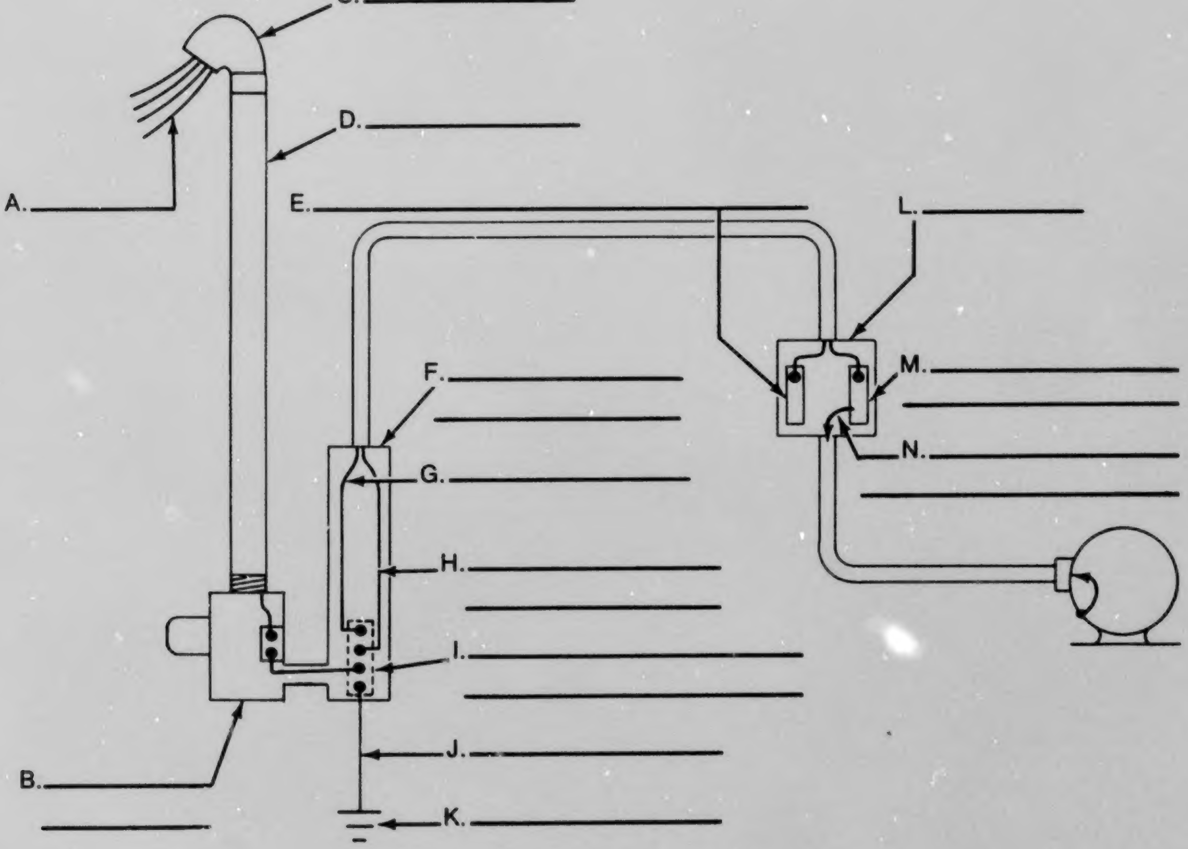
Grounding electrode

Subpanel

Equipment grounding bar (bonded)

Equipment grounding conductor to motor, other equipment, or housing

ASSIGNMENT SHEET #1


C.
D.
A.
E.
L.
F.
G.
M.
N.
H.
I.
J.
B.
K.

IN-PLANT DISTRIBUTION EQUIPMENT
UNIT II

ASSIGNMENT SHEET #2 — INTERPRET ABBREVIATIONS AND SYMBOLS ASSOCIATED WITH IN-PLANT DISTRIBUTION EQUIPMENT

NAME ______________________________ SCORE ______________

An electrical technician must be able to interpret electrical abbreviations and symbols in order to understand specifications. Below is a list of abbreviations and symbols. Give the meaning of each and describe where you would probably find it used.

A. X1, X2 . . .

____

____

____

B. H1, H2 . . .

____

____

____

C. Pf

____

____

____

D. hp

____

____

____

E. ϕ

____

____

____

ASSIGNMENT SHEET #2

F. LV

G. HV

H. *NEC*

I. ⏚

IN-PLANT DISTRIBUTION EQUIPMENT
UNIT II

ASSIGNMENT SHEET #3 — DRAW PROPER METER CONNECTIONS

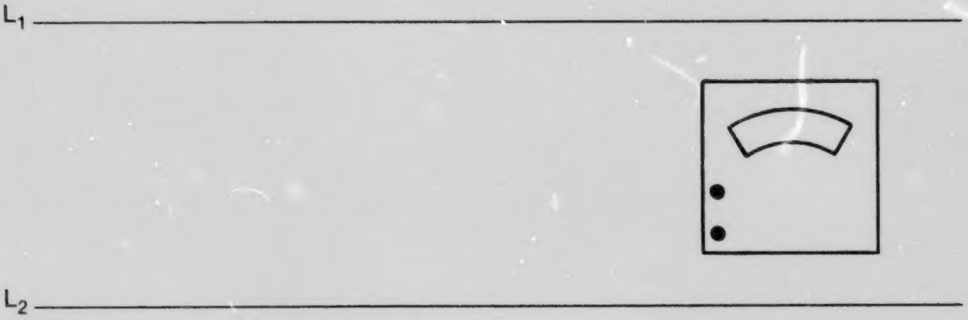
NAME ________________________________ SCORE ______________

The electrical technician must be able to read and draw schematic diagrams.

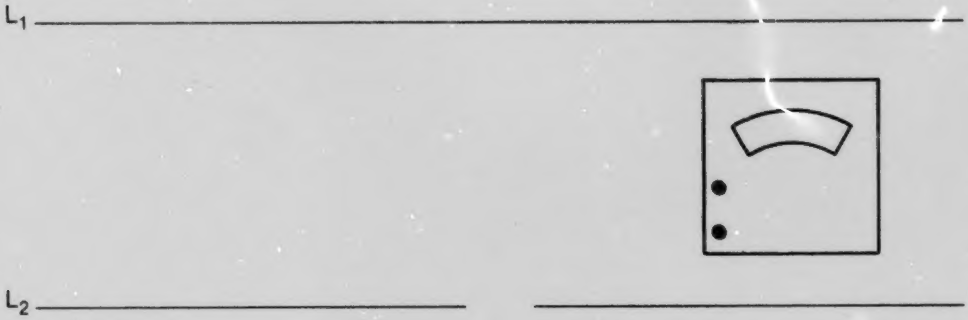
PART I

Draw the proper meter connections for the schematics of meter hookups on this and the following pages.

A. Single-phase voltmeter

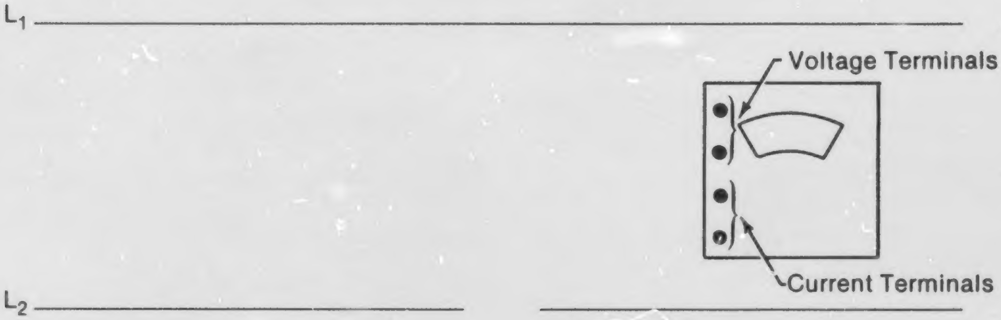


B. Single-phase ammeter



ASSIGNMENT SHEET #3

C. Single-phase wattmeter

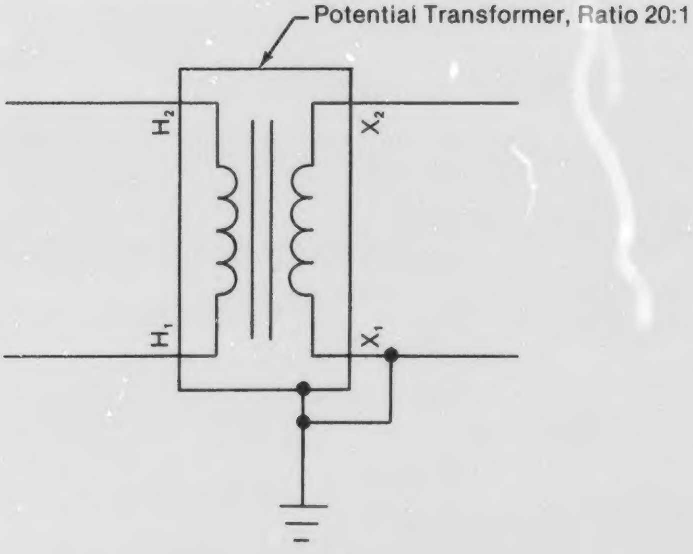

L_1
Voltage Terminals
Current Terminals
L_2

PART II

Draw the proper meter connections, and calculate voltage, amperage, and wattage, using the figures and ratios given in the following problems.

A. What is the primary voltage if the voltmeter reads 118 volts?

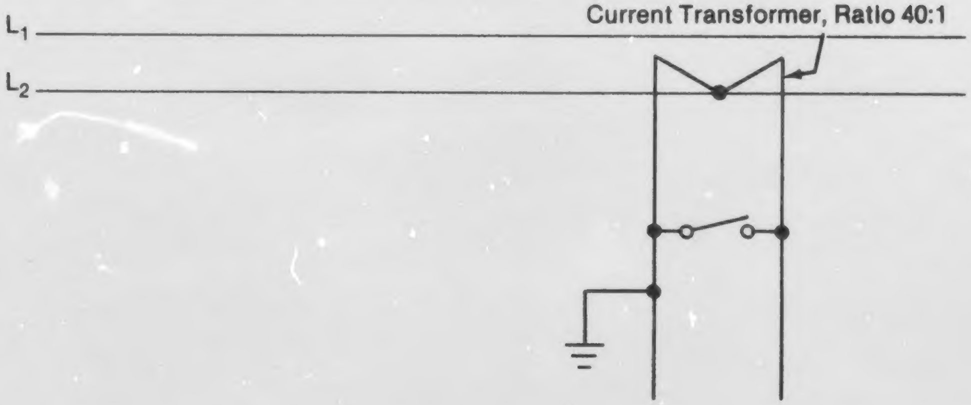
Primary voltage = ______________________


Potential Transformer, Ratio 20:1
H_2
X_2
H_1
X_1

ASSIGNMENT SHEET #3

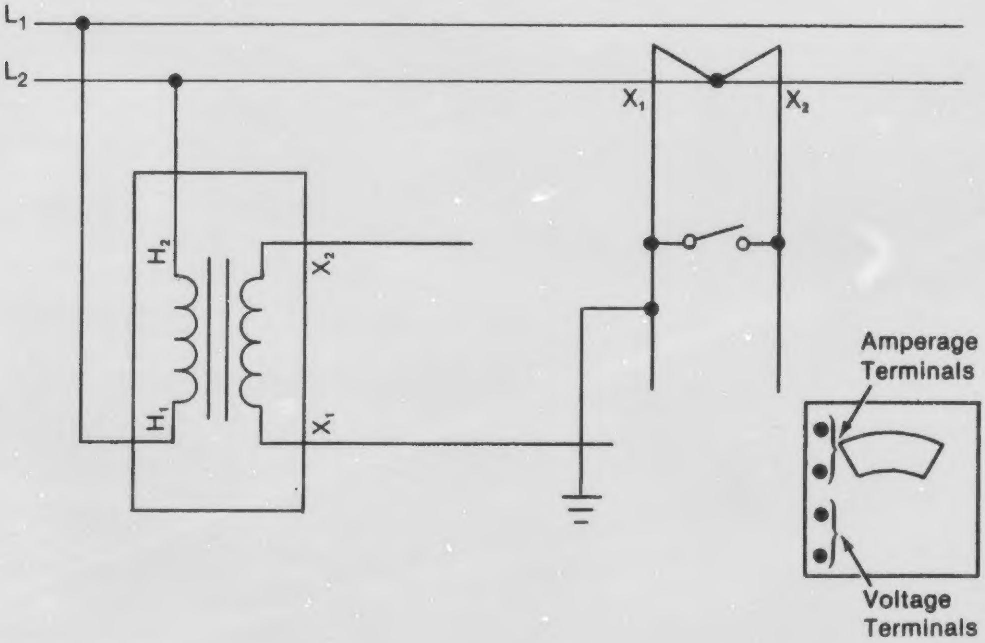
B. What is the line amperage if the ammeter reading is 4.5 amperes?

Line amperage = ______________________________


Current Transformer, Ratio 40:1
L_1
L_2

C. What is the line wattage if the potential transformer ratio is 20:1, the current transformer ratio is 40:1, and the wattmeter reads 56 watts?

Line wattage = ______________________________


L_1
L_2
X_1
X_2
H_2
X_2
H_1
X_1
Amperage Terminals
Voltage Terminals

IN-PLANT DISTRIBUTION EQUIPMENT
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. Neutral
B. Meter and meter base
C. Weather head
D. Service riser
E. Neutral bar (not bonded in subpanel)
F. Breaker box (panel or load center)
G. Neutral conductor (white)
H. Equipment grounding conductor (green or bare)
I. Grounded neutral and equipment ground wire bar (bonded)
J. Grounding-electrode conductor
K. Grounding electrode
L. Subpanel
M. Equipment grounding bar (bonded)
N. Equipment grounding conductor to motor, other equipment, or housing

Assignment Sheet #2

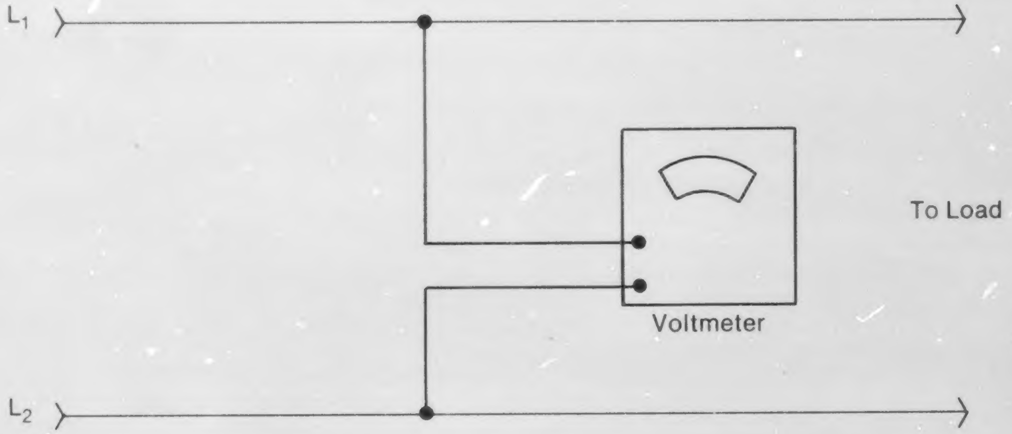
A. Secondary leads — Transformers
B. Primary leads — Transformers
C. Power factor — Electrical efficiency
D. Horsepower — Motors
E. Phase — Types of services
F. Low voltage — Motor windings
G. High voltage — Motor windings
H. *National Electrical Code* — Specifications
I. Ground — Schematic drawings

ANSWERS TO ASSIGNMENT SHEETS

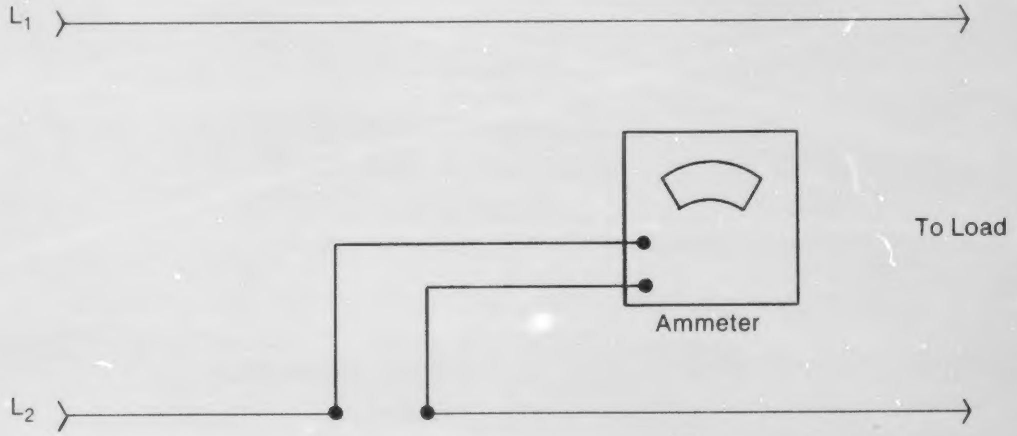
Assignment Sheet #3

PART I

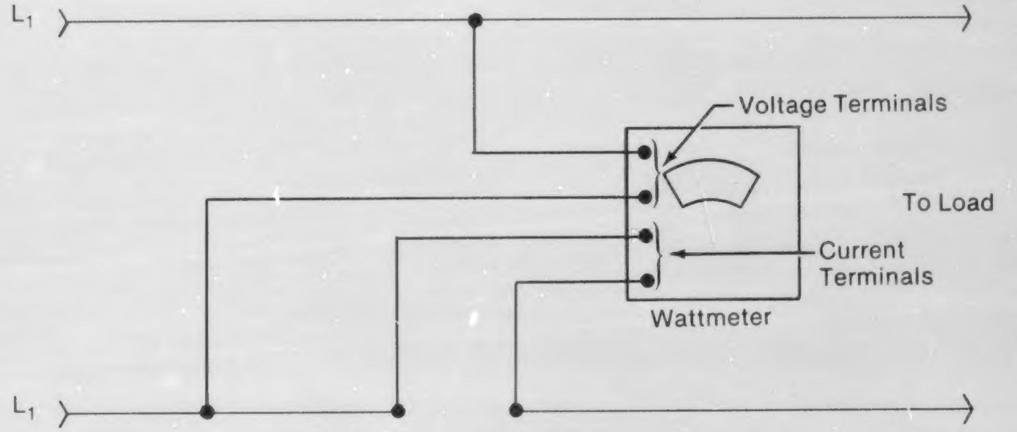
A.


L1
To Load
Voltmeter
L2

B.


L1
To Load
Ammeter
L2

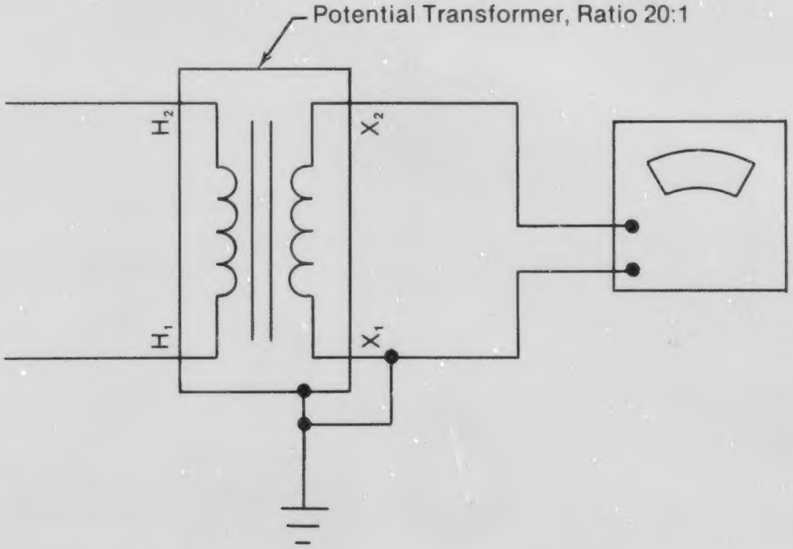
C.


L1
Voltage Terminals
To Load
Current Terminals
Wattmeter
L1

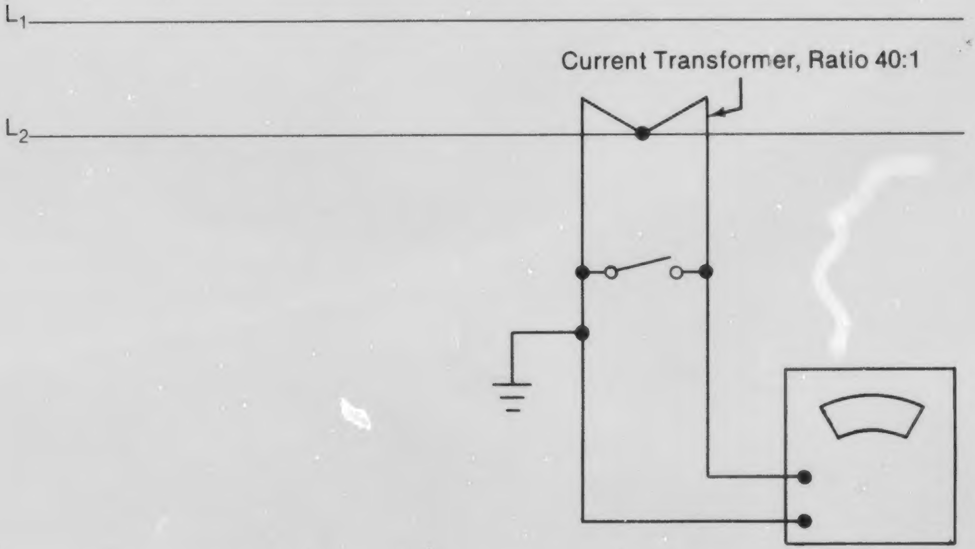
ANSWERS TO ASSIGNMENT SHEETS

PART II

A. Primary voltage = 20 × 118 = 2360

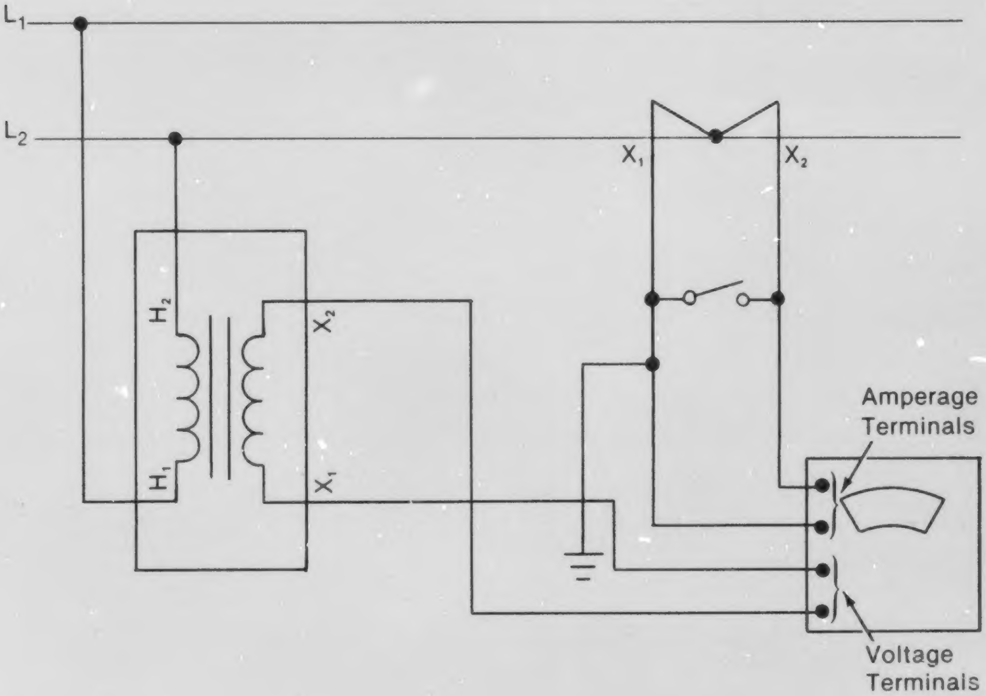

Potential Transformer, Ratio 20:1
H_2
H_1
X_2
X_1

B. Line amperage = 4.5 × 40 = 180.0


L_1
L_2
Current Transformer, Ratio 40:1

ANSWERS TO ASSIGNMENT SHEETS

C. Line wattage = 20 × 40 × 56 = 44,800 watts or 44.8 kilowatts


L_1
L_2
X_1
X_2
H_2
H_1
X_2
X_1
Amperage Terminals
Voltage Terminals

IN-PLANT DISTRIBUTION EQUIPMENT
UNIT II

JOB SHEET #1 — TEST TRANSFORMER TURN RATIOS

I. Equipment and materials

A. Transformer, rated 480 to 120/240 volts

B. Transformer, rated 240 to 24 volts

C. Transformer, rated 120 to 24 volts

D. Two voltmeters (one with 600-volt scale)

E. Wire or test jumpers to connect transformers to power supply

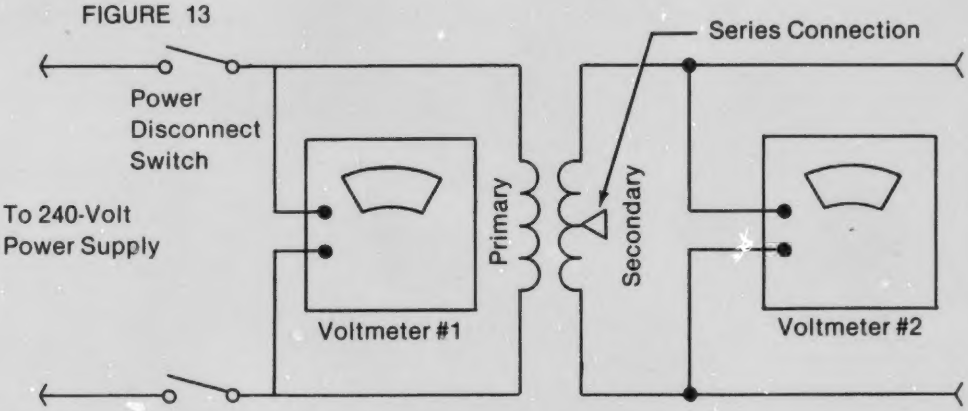
F. Single-phase power supply, 120/240-volt or 120/208-volt

II. Procedure

A. Connect both voltmeters to power supply, and adjust needles until both read the same at near midscale

B. Connect transformer as shown in Figure 13

FIGURE 13


Series Connection
Power Disconnect Switch
To 240-Volt Power Supply
Primary
Secondary
Voltmeter #1
Voltmeter #2

C. Double-check connections for correctness

D. Check to be sure that all leads are in the clear

(NOTE: Show work to instructor before proceeding.)

E. Energize power supply

JOB SHEET #1

F. Read both voltmeters

G. Record voltmeter readings for Transformer #1

VM #1 = ______________________________

VM #2 = ______________________________

H. Open power switch

I. Calculate actual transformer turn ratio

(NOTE: Divide Voltmeter #2 reading by Voltmeter #1 reading to find the ratio. Show your work.)

T#1 turn ratio = ______________________________

J. Compare calculated ratio with nameplate voltage ratio

(NOTE: Calculated ratio should match nameplate ratio within ± 1 percent.)

K. Test Transformer #2, using same procedure as that used to test Transformer #1

L. Record voltmeter readings for Transformer #2, and calculate turn ratio

(NOTE: Show your work.)

VM #1 = ______________________________

VM #2 = ______________________________

T#2 turn ratio = ______________________________

M. Test Transformer #3, using the same procedure as that used to test Transformer #1

JOB SHEET #1

N. Record voltmeter readings for Transformer #3, and calculate turn ratio

(NOTE: Show your work.)

VM #1 = ________________________________

VM #2 = ________________________________

T#3 turn ratio = ________________________________

(NOTE: Show results to instructor for evaluation and comments.)

O. Dismantle equipment and return to proper storage

IN-PLANT DISTRIBUTION EQUIPMENT
UNIT II

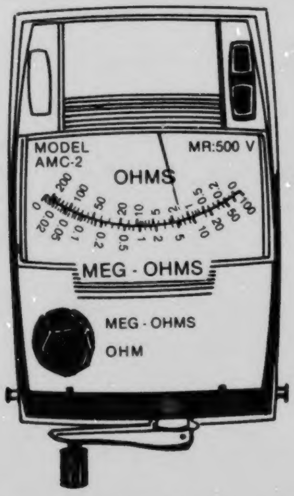
JOB SHEET #2 — TEST TRANSFORMER INSULATION RESISTANCE

I. Equipment

A. Three transformers (voltage not important; larger sizes if available)

B. Megger tester with leads (Figure 14)

FIGURE 14


MODEL
AMC-2
MR:500 V
OHMS
MEG - OHMS
MEG - OHMS
OHM

C. Test jumpers or wire to short windings

D. Centigrade-scale thermometer

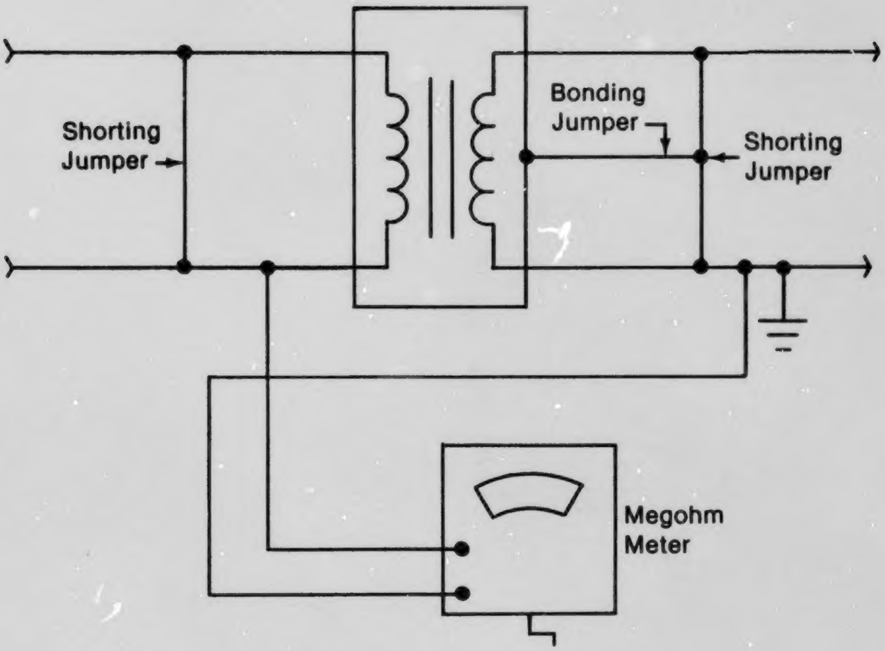
JOB SHEET #2

II. Procedure

A. Test primary winding to secondary and ground

1. Construct circuit as shown in Figure 15

FIGURE 15


Shorting Jumper
Bonding Jumper
Shorting Jumper
Megohm Meter

2. Short both windings

3. Ground the secondary winding to transformer case

4. As near as practical, place thermometer to get the temperature of the interior of the windings

5. Crank Megger tester at about 120 rpm for sixty seconds or until needle settles down

6. Read instrument while still cranking

7. Stop cranking

8. Record reading

Megger reading = ______________________ Megohms

JOB SHEET #2

9. Check thermometer

   (NOTE: Insulation resistance will decrease by 50 percent for every 10-degree centigrade rise in temperature, or double for every 10-degree centigrade drop in temperature.)

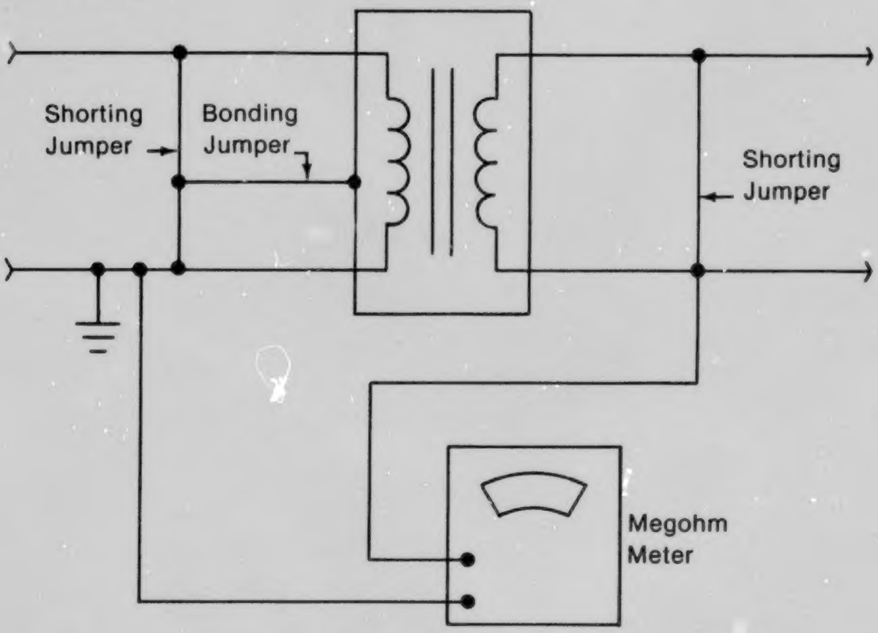
10. Record temperature

    Temperature = ________________________ °C

    (NOTE: Megohm readings become more meaningful when periodic tests are made on a piece of equipment, and then plotted on graph paper to make a curve.)

B. Test secondary to primary and ground (Figure 16)

FIGURE 16



1. Short both windings
2. Ground the primary winding to transformer case
3. Make test as before (steps 4 through 10) on primary insulation

   Megger reading = ________________________ Megohms

   Temperature = ________________________ °C

   (NOTE: Show results to instructor for evaluation.)

JOB SHEET #2

C. Repeat procedure on each remaining transformer

1. Transformer #2

   T2 Megger reading = ________________________________ Megohms

   T2 temperature = ________________________________ °C

2. Transformer #3

   T3 Megger reading = ________________________________ megohms

   T3 temperature = ________________________________ °C

   (NOTE: Show results to instructor for evaluation and comments.)

D. Dismantle equipment and return to proper storage

IN-PLANT DISTRIBUTION EQUIPMENT
UNIT II

JOB SHEET #3 — CALCULATE POWER FACTOR AND INSTALL CAPACITOR TO IMPROVE POWER FACTOR

I. Equipment

A. Single-phase power supply, 240-volt, 30-ampere capacity

B. Run capacitor, 440 volt, 7.5 microfarad

C. Wattmeter with leads, 240 volt, 10 ampere

D. Voltmeter with leads, 300 volt

E. Clamp-on ammeter

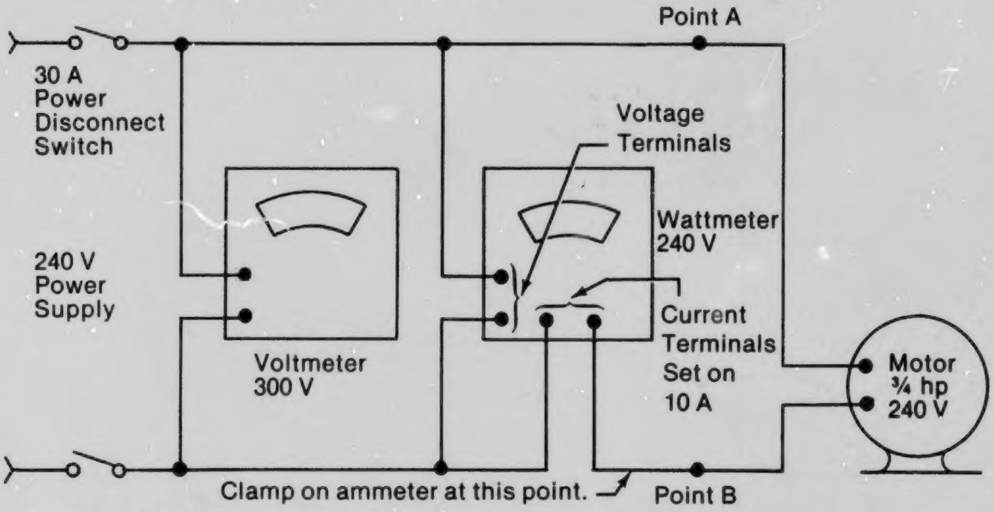
F. Single-phase motor, 3/4 horsepower, 240 volt

G. Test jumpers or wire to connect apparatus

II. Procedure

A. Construct circuit as shown in Figure 17

FIGURE 17


Point A
30 A Power Disconnect Switch
Voltage Terminals
Wattmeter 240 V
240 V Power Supply
Current Terminals Set on 10 A
Voltmeter 300 V
Motor ¾ hp 240 V
Clamp on ammeter at this point.
Point B

B. Double-check correctness of connections

C. Close 30-ampere disconnect switch

JOB SHEET #3

D. Read voltmeter and record

Volts = ______________________________

E. Read ammeter and record

Amperes = ______________________________

F. Read wattmeter and record

Watts = ______________________________

G. Open 240-volt main power switch

H. Calculate power factor

(NOTE: Show your work.)

Pf = ______________________________

I. Install 440-volt, 7.5-microfarad run capacitor in circuit at points A and B shown in Figure 14

J. Double-check connections and all leads

K. Close 240-volt main power switch

L. Take readings as before and record

Volts = ______________________________

Amperes = ______________________________

Watts = ______________________________

M. Open 240-volt main power switch

N. Again calculate power factor

(NOTE: Show your work.)

Pf = ______________________________

(NOTE: Show work to instructor for evaluation and comment.)

O. Dismantle equipment and return to proper storage

IN-PLANT DISTRIBUTION EQUIPMENT
UNIT II

TEST

NAME ______________________________ SCORE ______________

1. Match to their correct definitions terms associated with in-plant distribution equipment. Write the correct numbers in the blanks. Terms and definitions continue on the following page.

______a. Conductor used to connect non-current-carrying metal parts of equipment to the system-grounded conductor or grounding-electrode conductor

______b. Circuit conductors between final overcurrent device protecting circuit and the outlet

______c. Supply conductors that extend from transformers to the service equipment

______d. System or circuit conductor that is intentionally grounded

______e. All circuit conductors between service equipment or generator switchboard of an isolated plant and final branch-circuit overcurrent device

______f. Connected to earth or to some conducting body that serves in place of the earth

______g. Ratio of true power (watts) to apparent power (volts times amperes) of an alternating-current circuit or system

______h. Conductors and equipment for receiving energy from electrical supply system to the premises wiring

______i. To connect electrical equipment either intentionally or accidentally to the earth or to some conducting body that serves as the earth

______j. Conductor used to connect grounding electrode to the equipment grounding conductor or to grounding conductor of circuit at service equipment or at source of separately derived system

1. Grounded conductor
2. Ground
3. Feeder
4. Power factor
5. Grounded
6. Branch circuit
7. Service equipment
8. Grounding-electrode conductor
9. Equipment grounding conductor
10. Service conductors

TEST

_____k. Electrical discharge on surface of high-voltage equipment producing free oxygen ions (ozone)

_____l. Device that provides ozone-resistant insulation at the termination of shielding on a high-voltage conductor

_____m. Connection between two or more portions of equipment grounding conductor

_____n. A reliable conductor to assure the required electrical conductivity between metal parts required to be electrically connected

_____o. Connecting metallic parts to assure electrical continuity with capacity to conduct any current likely to be imposed

_____p. Connection between grounded circuit conductor and equipment grounding conductor at the service

_____q. Connection between portions of a conductor in a circuit to maintain required ampacity

11. Corona
12. Stress cone
13. Bonding
14. Bonding jumper
15. Circuit bonding jumper
16. Equipment bonding jumper
17. Main bonding jumper

2. Write meanings of abbreviations and symbols associated with in-plant distribution equipment.

a. HV — ____________________

b. LV — ____________________

c. ϕ — ____________________

d. hp — ____________________

e. Pf — ____________________

f. H1, H2 . . . — ____________________

g. X1, X2 . . . — ____________________

h. *NEC* — ____________________

i. ⏚ — ____________________

TEST

3. State the maintenance electrician's motto.

a. ____________________

b. ____________________

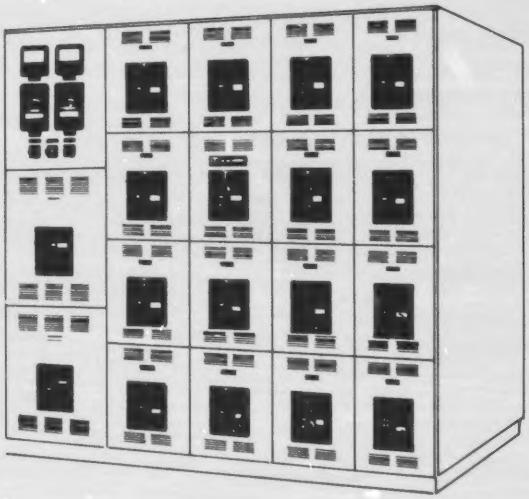
c. ____________________

d. ____________________

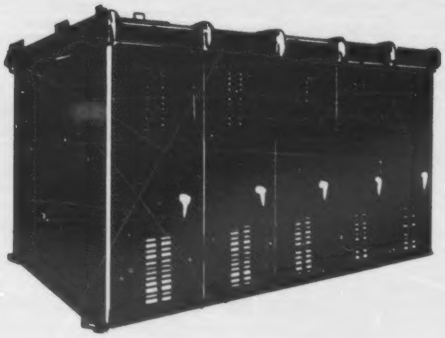
e. ____________________

4. Distinguish between indoor and outdoor electrical distribution equipment. Write an "I" in the blank before indoor distribution equipment and an "O" in the blank before outdoor distribution equipment.

______a.



______b.



TEST

5. Name types of service-entrance conductors.

a. ______________________________

____

b. ______________________________

____

c. ______________________________

____

d. ______________________________

____

6. Explain reasons for using stress cones.

a. ______________________________

____

b. ______________________________

____

c. ______________________________

____

7. Match different types of transformers to their general uses. Write the correct numbers in the blanks.

_____a. Used indoors, usually in the interior of large plants, or used outdoors with weatherproof housing

_____b. Used only in outdoor locations due to fire hazards

_____c. Used for metering and relay protection

_____d. Used to feed 120-volt receptacles where the system voltage is high

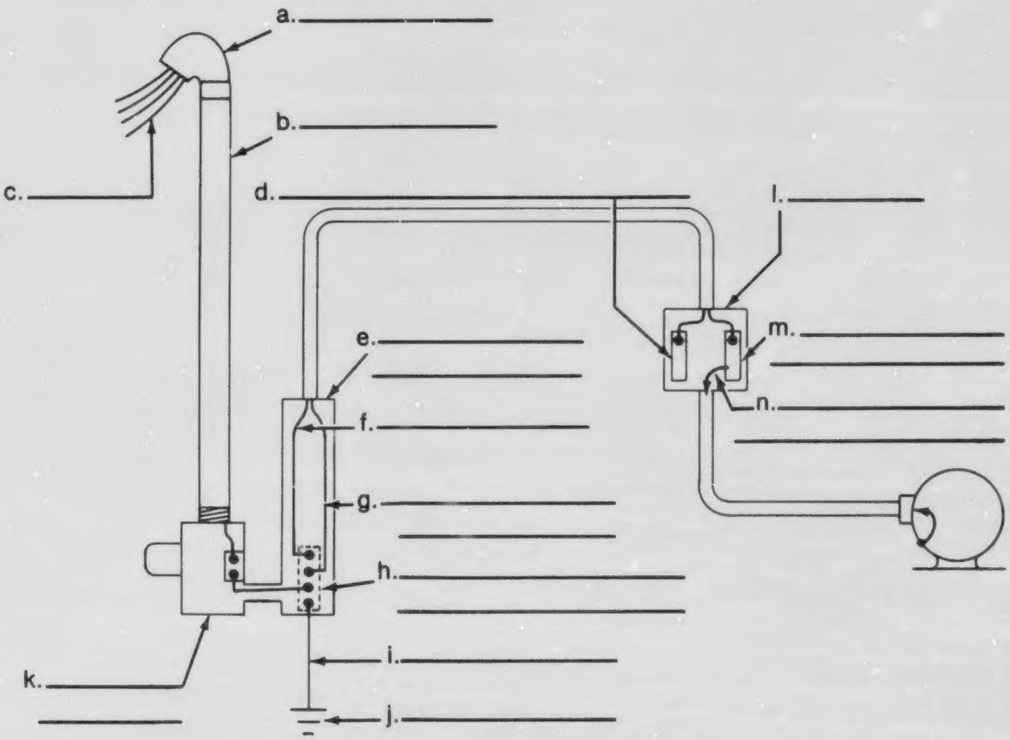
_____e. Used for metering and relaying

1. Air-cooled dry-type
2. Instrument: Potential transformer
3. Compound-filled dry-type
4. Oil-filled
5. Instrument: Current transformer

TEST

8. Identify components of the electrical equipment grounding system illustrated below. Write the correct names in the blanks.

Subpanel
Neutral bar (not bonded in subpanel)
Breaker box (panel or load center)
Grounding-electrode conductor
Neutral conductor (white)
Grounding electrode
Meter and meter base
Service riser
Neutral
Weather head
Grounded neutral and equipment ground wire bar (bonded)
Equipment grounding bar (bonded)
Equipment grounding conductor to motor, other equipment, or housing
Equipment grounding conductor (green or bare)

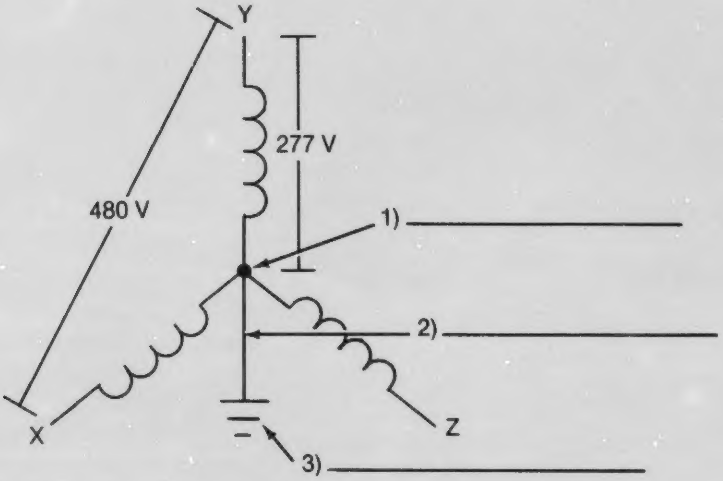


TEST

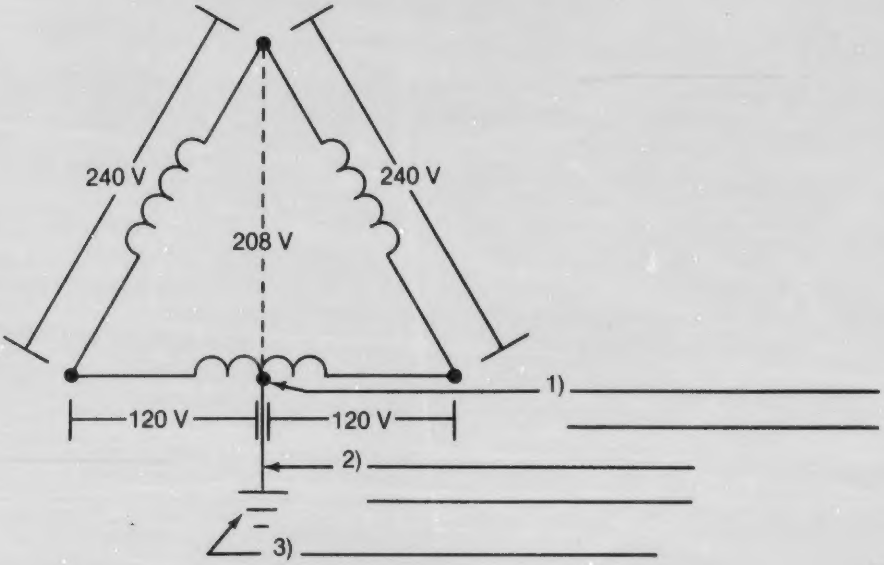
9. Identify points of delta and wye electrical system grounding. Write the correct names in the blanks.

Grounding electrode
Grounding-electrode conductor
Grounding point on electrical system

a. 277/480-volt wye system grounding


Y
277 V
480 V
1) ____________________
2) ____________________
X
Z
3) ____________________

b. 120/240-volt delta system grounding


240 V
240 V
208 V
1) ____________________
____
120 V
120 V
2) ____________________
____
3) ____________________

TEST

10. Calculate power factor for a single-phase alternating-current circuit. Show your work.

Formula: $\text{Pf} = \dfrac{W}{V \times A}$

Where Volts = 480
Amps = 33
Watts = 10,400

Pf = ________________________________

11. Distinguish between feeder and branch circuits. Write "FC" in the blank before feeder circuit, and "BC" in the blank before branch circuit.

_____a. Consists of circuit conductors between final overcurrent device protecting the circuit and the outlet(s)

_____b. Consists of all circuit conductors between the service equipment, or generator switchboard of an isolated plant, and the final branch-circuit overcurrent device

12. Match meters to their proper switchboard connections. Write the correct numbers in the blanks.

_____a. Connects in series with the line

_____b. Connects across the line for potential and in series for current

_____c. Connects across the line

1. Voltmeter
2. Ammeter
3. Wattmeter

(NOTE: Test questions 13 and 14 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

13. Draw proper meter connections.

14. Demonstrate the ability to

a. Test transformer turn ratios.

b. Test transformer insulation resistance.

c. Calculate power factor, and install capacitor to improve power factor.

IN-PLANT DISTRIBUTION EQUIPMENT
UNIT II

ANSWERS TO TEST

1.

a.	9	f.	5	k.	11	p.	17
b.	6	g.	4	l.	12	q.	15
c.	10	h.	7	m.	16		
d.	1	i.	2	n.	14		
e.	3	j.	8	o.	13		

2. a. High voltage
   b. Low voltage
   c. Phase
   d. Horsepower
   e. Power factor
   f. Primary leads
   g. Secondary leads
   h. *National Electrical Code*
   i. Ground

3. a. Keep it clean
   b. Keep it dry
   c. Keep it tight
   d. Keep it cool
   e. Keep it simple

4 a. I
   b. O

5. a. Thermoplastic insulated
   b. Shielded cable
   c. Copper or aluminum busbars with heavy, bolted connections
   d. Polyethylene

ANSWERS TO TEST

6. a. To prevent entrance of moisture and to avoid giving rise to corona
   b. To relieve the concentration of voltage stress and corona at point where shielding ends
   c. To prevent premature cable failure

7. a. 1
   b. 4
   c. 5
   d. 3
   e. 2

8. a. Weather head
   b. Service riser
   c. Neutral
   d. Neutral bar (not bonded in subpanel)
   e. Breaker box (panel or load center)
   f. Neutral conductor (white)
   g. Equipment grounding conductor (green or bare)
   h. Grounded neutral and equipment ground wire bar (bonded)
   i. Grounding-electrode conductor
   j. Grounding electrode
   k. Meter and meter base
   l. Subpanel
   m. Equipment grounding bar (bonded)
   n. Equipment grounding conductor to motor, other equipment, or housing

9. a. 227/480-volt wye system grounding
      1) Grounding point on electrical system
      2) Grounding-electrode conductor
      3) Grounding electrode

ANSWERS TO TEST

   b. 120/240-volt delta system grounding
      1) Grounding point on electrical system
      2) Grounding-electrode conductor
      3) Grounding electrode

10. Pf = 0.65+

11. a. BC
    b. FC

12. a. 2
    b. 3
    c. 1

13. Evaluated to the satisfaction of the instructor

14. Performance skills evaluated to the satisfaction of the instructor

ELECTRICAL DIAGRAMS
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to construct and interpret electrical diagrams. The student will show this knowledge by completing the assignment sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with electrical diagrams.
2. State characteristics of wiring diagrams.
3. State characteristics of ladder diagrams.
4. State characteristics of one-line diagrams.
5. Identify wiring and ladder diagram symbols.
6. Arrange in order major steps in constructing a ladder diagram.
7. Construct a basic ladder diagram.
8. Identify electrical symbols in a wiring diagram.

ELECTRICAL DIAGRAMS
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order materials to supplement unit.

1. For student practice, obtain air conditioning compressors from your school's air conditioning program.

2. Disable a unit by loosening or cutting a wire and installing a bad relay. Or, provide another problem so that students may practice troubleshooting a defective unit.

3. Make copies of simple ladder diagrams from *Electrical Motor Controls* by Gary Rockis and Glen Mazur, available from American Technical Publishers Incorporated, 12235 South Laramie Avenue, Alsip, Illinois 60658.

B. Invite a factory representative from Bussmann Fuse Manufacturing Company or another fuse manufacturing company to give a presentation to the class on fuses and fuse coordination.

C. Make transparencies.

D. Provide students with objective sheet.

E. Discuss unit and specific objectives.

F. Provide students with information and assignment sheets.

G. Discuss information and assignment sheets.

1. Introduce terms associated with electrical diagrams, using Information Sheet, Section I and Transparency #1. Have several pieces of equipment available (a contactor, some push buttons, a relay, a timer) to assist the students in grasping the names of particular pieces of equipment.

2. Discuss the characteristics of pictorial and regular wiring diagrams, using Information Sheet, Section II and Transparencies #2 and #3. Most machines, including those on your campus, have a wiring diagram placed inside of them, especially such machines as machine shop lathes and mills and computer numerical-controlled machines. Show students a machine and its wiring diagram. Discuss with the students the confusion that could result if the technician were to troubleshoot using only a wiring diagram.

SUGGESTED ACTIVITIES

3. Discuss the characteristics of ladder diagrams, using Information Sheet, Section III, Transparency #1, and the copies of ladder diagrams you made from *Electrical Motor Controls.* Show students a ladder diagram from an actual machine, and discuss the ease with which troubleshooting can be done using a ladder diagram. Point out that the ladder diagram does not attempt to show the physical relationships of the individual parts.

4. Discuss what information must be shown on one-line diagrams, using Information Sheet, Section IV and Transparency #4. Make sure that the student understands that the purpose of one-line diagrams is to show the routing of major power from the incoming transmission or distribution line to the particular load. One-line diagrams assist the electrician in determining the size of service and subpanels.

5. Discuss wiring and line diagram symbols, using Information Sheet, Section V and Assignment Sheet #2. Impress on the students the importance of being able to interpret these symbols. Use actual equipment from the shop to show time-delay relays, standard relays, and some of the limit switches. Show the students how the terminals symbolized on paper match the terminals in the actual equipment.

6. Discuss the major steps in building a ladder diagram, using Information Sheet, Section VI and Assignment Sheet #1. Explain how to number and reference each rung of the ladder. Give students copies of simple ladder diagrams to use as guidelines for the general pattern they should follow to complete Assignment Sheet #1.

H. Give test.

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Ladder Diagram
2. TM #2 — Wiring Diagram
3. TM #3 — One-Line Diagram

SUGGESTED ACTIVITIES

E. Assignment sheets
   1. Assignment Sheet #1 — Construct a Basic Ladder Diagram
   2. Assignment Sheet #2 — Identify Electrical Symbols in a Wiring Diagram

F. Answers to assignment sheets

G. Test

H. Answers to test

III. Unit reference — Rockis, Gary, and Glen Mazur. *Electrical Motor Controls.* Alsip, Illinois: American Technical Publishers, Inc., 1982.

ELECTRICAL DIAGRAMS
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Wiring diagram — Schematic consisting of symbols and lines that indicate all connections and placement of all component parts in a device or circuit, including the power circuit wiring

B. Ladder diagram (line diagram) — Schematic consisting of symbols and lines that indicate power source and how current flows through various parts of a control circuit

C. One-line diagram — Schematic consisting of single-phase and three-phase power lines; indicates power distribution and fuse and interrupter coordination

D. Across-the-line — Method of starting an electric motor by connecting it directly to supply line

E. Automatic starting — Pertaining to self-acting starter completely controlled by pilot switches or some other sensing device

F. Auxiliary contact — Contact provided in addition to the main circuit contacts but operated with the main contacts

G. Bimetal — Two different metals bonded to provide fast heat transfer to trip contacts by mechanical deflection

(NOTE: Bimetals are used in thermal overload relays.)

H. Contactor — Device without overload protection; repeatedly establishes and interrupts an electric power circuit

I. Full voltage control — Function of magnetic control that connects equipment directly to line supply on starting

J. Jogging (inching) — Momentarily operating; moving driven machine a small distance

K. Magnetic contactor — Contactor operated electromechanically

L. Multispeed starter — Starter designed to start motor at a reduced speed and build to full speed in preset steps

INFORMATION SHEET

M. Overload relay — Device for protecting motor from overload current or voltage

(NOTE: An overload relay does not necessarily protect against short circuit, but does cause and maintain interruption from power supply until reset.)

N. Push button — Switch, manually operable plunger, button, or actuating device

O. Relay — Electromechanical device operated by a coil; uses contacts to make or break circuits

P. Remote control — Device that controls electrical apparatus from some distance

Q. Selector switch — Manually operated multiposition switch

(NOTE: The selector switch is also called a *multiple-contact switch.*)

R. Starter — Control device with electric contactor and overload protection; designed to protect motor from voltage inrush during starting

S. Timer — Pilot device that delays closing or opening of a circuit for a specific time; may be motor driven, solenoid-actuated, or electric

II. Characteristics of wiring diagrams (Transparency #2; Assignment Sheet #2)

A. Show components in their approximate locations

B. Provide guide for field wiring

C. Use electrical symbols

D. Show high and low voltage lines together

E. Make circuits difficult to trace

III. Characteristics of ladder diagrams (Transparency #1; Assignment Sheet #1)

A. Resemble a ladder

B. Depict individual circuits as ladder rungs

C. Use electrical symbols

D. Separate high and low voltages

E. Simplify circuit troubleshooting

INFORMATION SHEET

IV. Characteristics of one-line diagrams (Transparency #3)

(NOTE: No single one-line diagram has all of the characteristics listed below. The purpose of a one-line diagram is to show the routing of major power from the incoming transmission or distribution line to the particular load. One-line diagrams assist the electrician in determining the size of service and subpanels.)

A. Power company one-line diagrams

1. Show electrical transmission or distribution lines
2. Show sectionalizing points
3. Show location of transformers

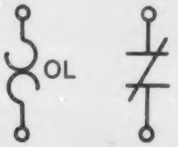
B. Industrial plant one-line diagrams

1. Show location of transformers
2. Show location of switches or breakers
3. Show location of fuses
4. Indicate size of fuses
5. Indicate size of loads
6. Indicate characteristics of loads

V. Wiring and ladder diagram symbols (Figures 1-28)

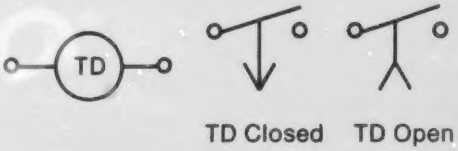
A. Thermal overload relay

FIGURE 1



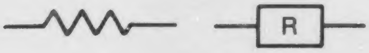
B. Time delay relay

FIGURE 2



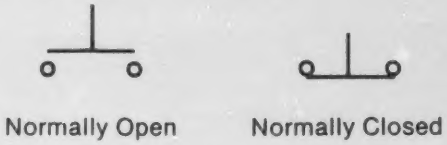
C. Standard resistor

FIGURE 3



D. Standard push-button switch

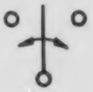
FIGURE 4



INFORMATION SHEET

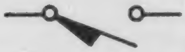
E. Plugging switch

FIGURE 5



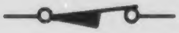
F. Limit switch (normally open)

FIGURE 6



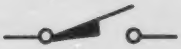
G. Limit switch (normally closed)

FIGURE 7



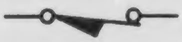
H. Limit switch (held open)

FIGURE 8



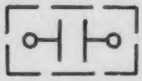
I. Limit switch (held closed)

FIGURE 9



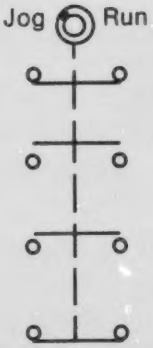
J. Two-wire pilot device

FIGURE 10



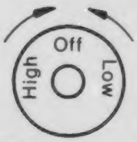
K. "Roto-push" selector push button, two-position selector ring switch

FIGURE 11



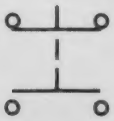
L. Three-position selector switch, mechanically coupled

FIGURE 12



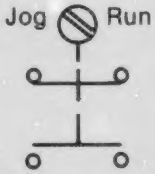
M. Two-circuit push button

FIGURE 13



N. Two-position selector switch

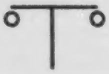
FIGURE 14



INFORMATION SHEET

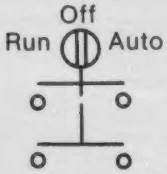
O. Toggle-operated manual switch (wobble stick)

FIGURE 15



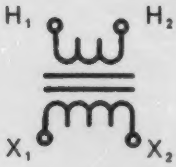
P. Three-position selector switch

FIGURE 16


Off
Run
Auto

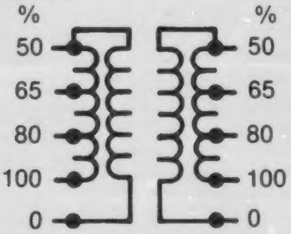
Q. Single-voltage transformer

FIGURE 17



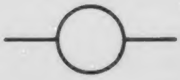
R. Auto-transformer for reduced voltage starting

FIGURE 18


%
%
50
50
65
65
80
80
100
100
0
0

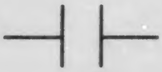
S. Single-voltage magnet coil

FIGURE 19



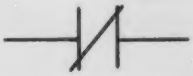
T. Contact (normally open)

FIGURE 20



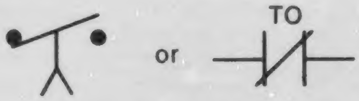
U. Contact (normally closed)

FIGURE 21



V. Contact (timed open)

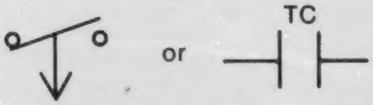
FIGURE 22



INFORMATION SHEET

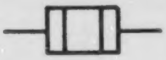
W. Contact (timed closed)

FIGURE 23



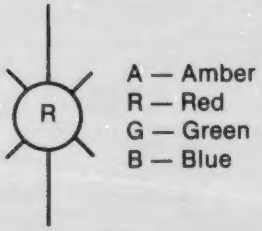
X. Standard fuse

FIGURE 24



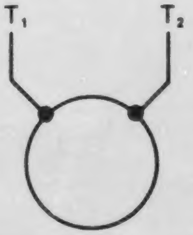
Y. Standard indicator light

FIGURE 25


R
A — Amber
R — Red
G — Green
B — Blue

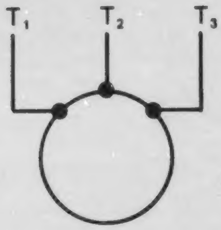
Z. Single-phase AC motor

FIGURE 26



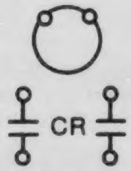
AA. Three-phase AC motor

FIGURE 27



BB. Control relay

FIGURE 28

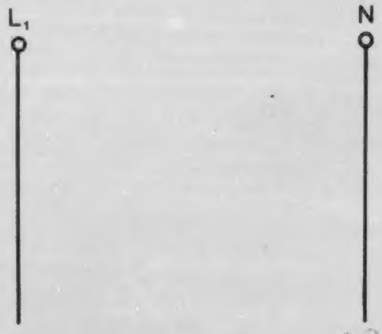


VI. Major steps in constructing a ladder diagram (Figures 29-33; Assignment Sheet #1)

A. Establish and label power lines

EXAMPLE:

FIGURE 29

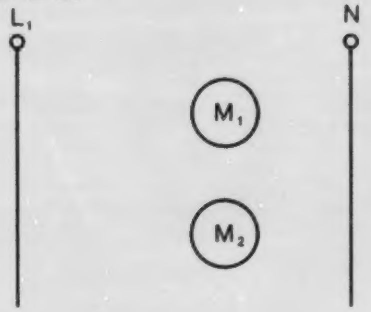


INFORMATION SHEET

B. Identify and label loads

EXAMPLE:

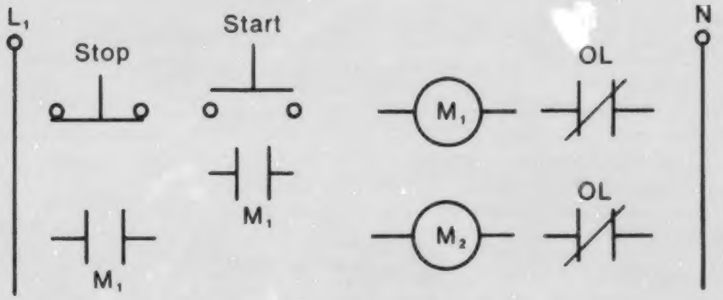
FIGURE 30



C. Identify and label control devices and contacts for each circuit

EXAMPLE:

FIGURE 31

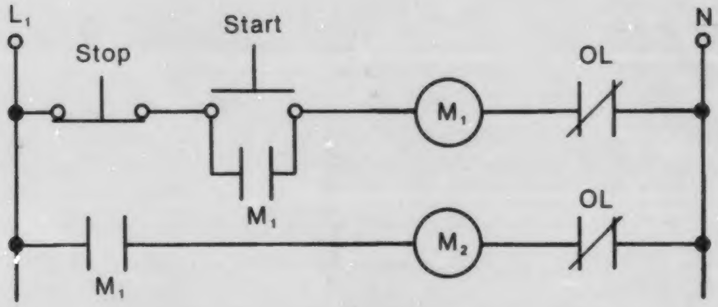

L_1
Start
Stop
OL
N
M_1
M_1
OL
M_1
M_2

INFORMATION SHEET

D. Connect circuit wires, keeping ladder rungs equidistant for ease of reading

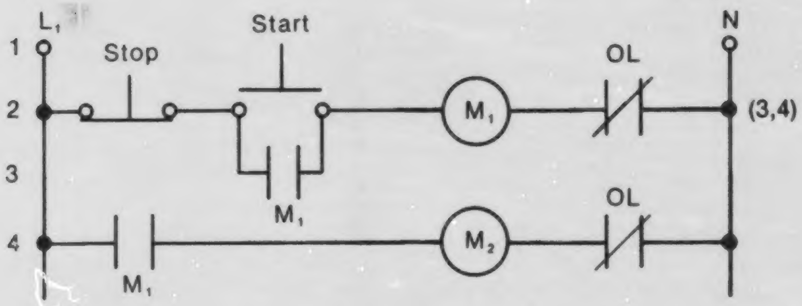
EXAMPLE:

FIGURE 32

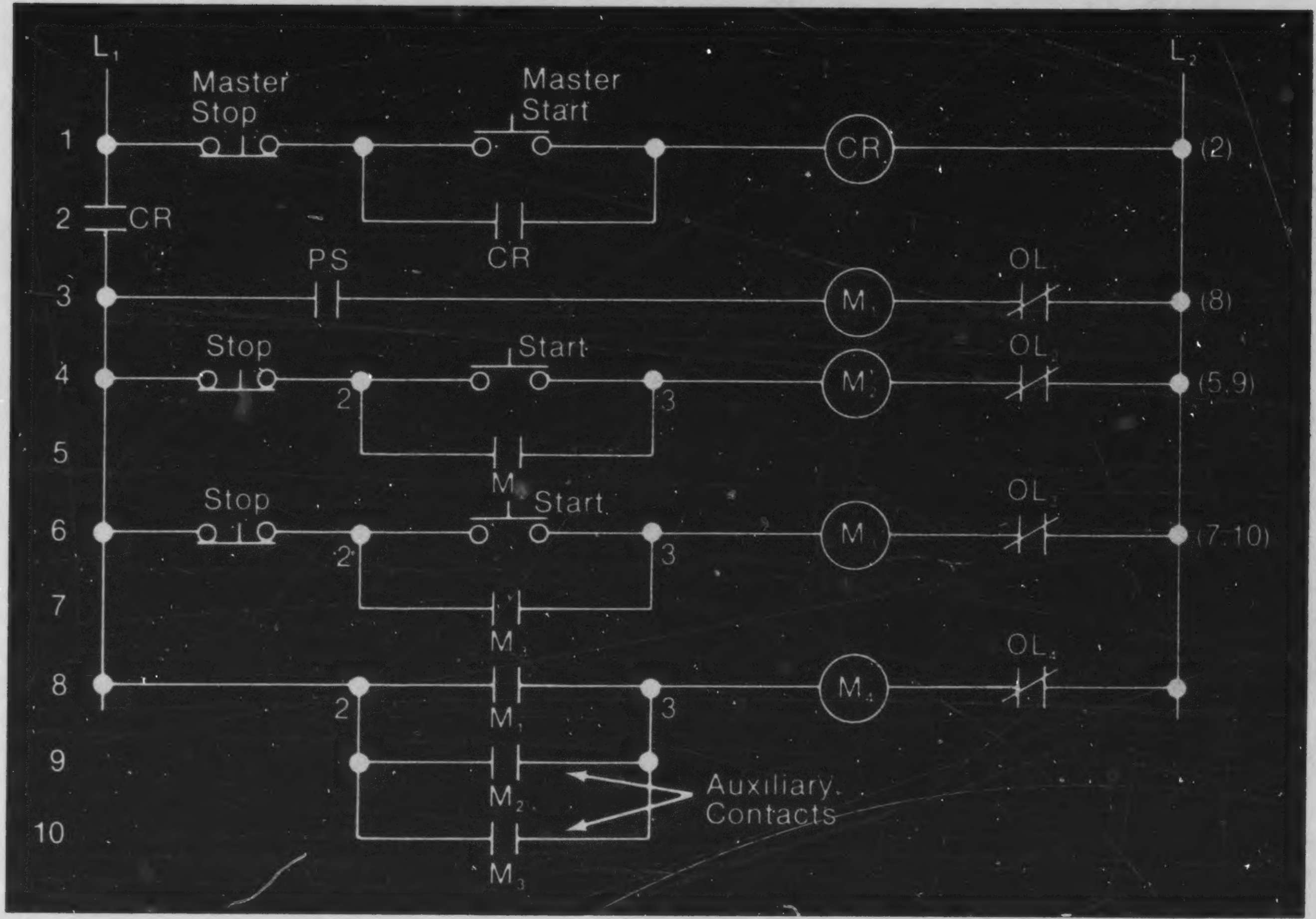

L₁
Start
N
Stop
OL
M₁
M₁
OL
M₂
M₁

E. Number rungs, and cross reference

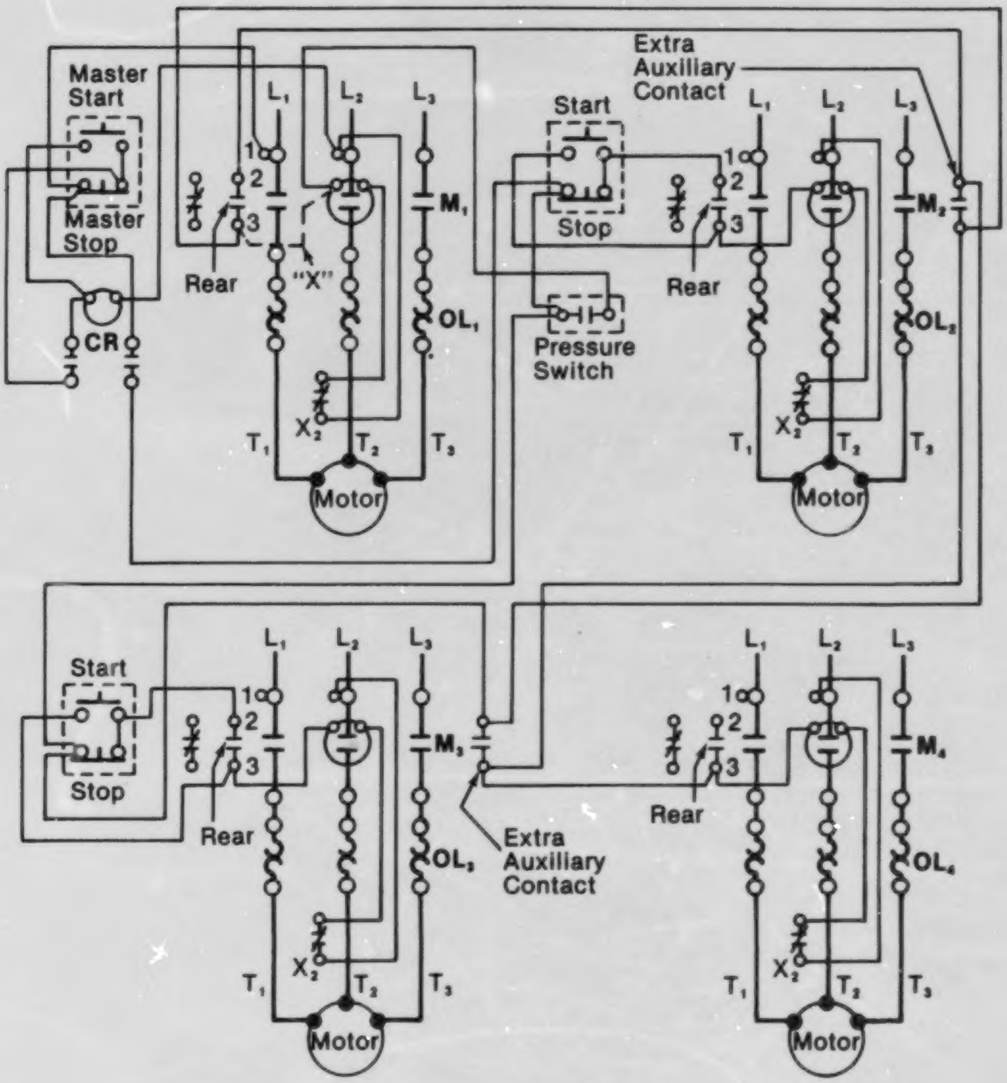
FIGURE 33


L₁
Start
N
1
Stop
OL
2
M₁
(3,4)
3
M₁
OL
4
M₂
M₁

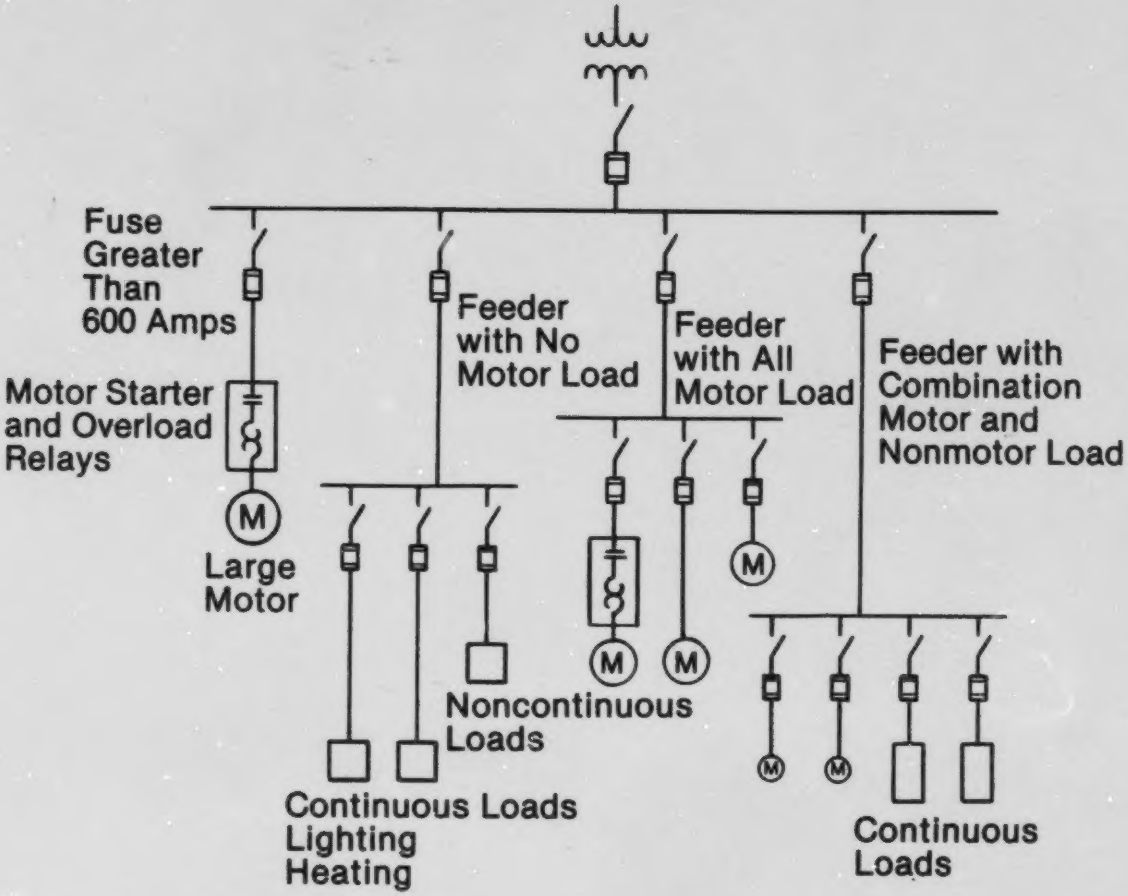
Ladder Diagram


L_1
L_2
Master Stop
Master Start
CR
(2)
1
2
CR
CR
3
PS
M_1
OL_1
(8)
4
Stop
Start
2
3
M_2
OL_2
(5,9)
5
M_2
6
Stop
Start
2
3
M_3
OL_3
(7,10)
7
M_3
8
2
3
M_1
M_4
OL_4
9
M_2
Auxiliary Contacts
10
M_3

Wiring Diagram


Master Start
Master Stop
CR
L1
L2
L3
1
2
3
Rear
"X"
M1
OL1
X2
T1
T2
T3
Motor
Start
Stop
Pressure Switch
Extra Auxiliary Contact
M2
OL2
M3
OL3
M4
OL4

One-Line Diagram


Fuse Greater Than 600 Amps
Motor Starter and Overload Relays
M
Large Motor
Feeder with No Motor Load
Feeder with All Motor Load
Feeder with Combination Motor and Nonmotor Load
M
M
M
Noncontinuous Loads
Continuous Loads Lighting Heating
M
M
Continuous Loads

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TM #3

IED · 129-C

ELECTRICAL DIAGRAMS
UNIT III

ASSIGNMENT SHEET #1 — CONSTRUCT A BASIC LADDER DIAGRAM

NAME ______________________________ SCORE ______________

The electrical technician must be able to draw and read ladder diagrams to facilitate troubleshooting procedures.

In the space provided below, draw, label, and reference a ladder diagram with the following components: 120 VAC fused power supply, three loads, two single-pole single-throw (SPST) switches, and one control relay with a line voltage coil. Each load is to be a parallel circuit. Control two loads with the relay, one load with an SPST switch, and the relay coil with an SPST switch.

ELECTRICAL DIAGRAMS
UNIT III

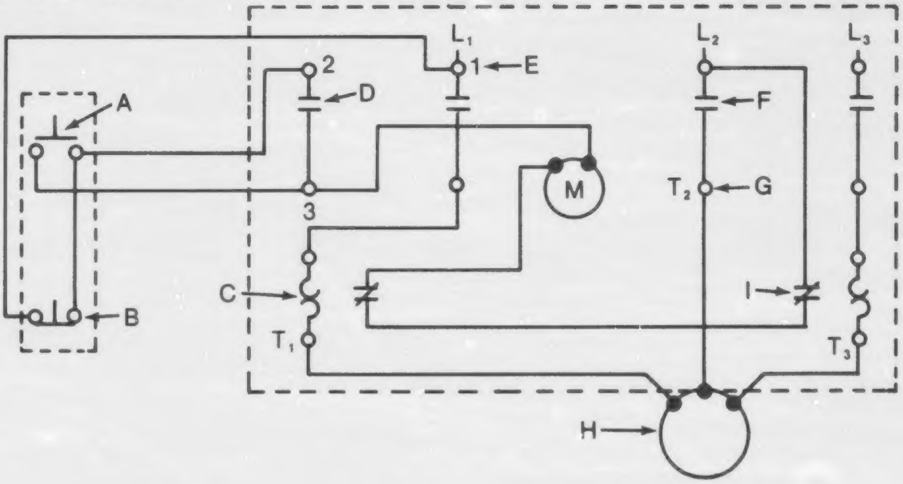
ASSIGNMENT SHEET #2 — IDENTIFY ELECTRICAL SYMBOLS IN A WIRING DIAGRAM

NAME ______________________________ SCORE ______________

The electrical technician must be able to identify electrical symbols in a wiring diagram in order to recognize all component parts in a device or circuit.

Identify the electrical symbols used in the wiring diagram illustrated below. Write the correct answers in the blanks.

Line and control wiring terminal
Normally closed push button (stop)
Three-phase motor
Overload device switch
Normally open push button (start)
T2 motor lead terminal
Auxiliary contact
Thermal overload relay
Main contact



A. ______________________

B. ______________________

C. ______________________

D. ______________________

E. ______________________

F. ______________________

G. ______________________

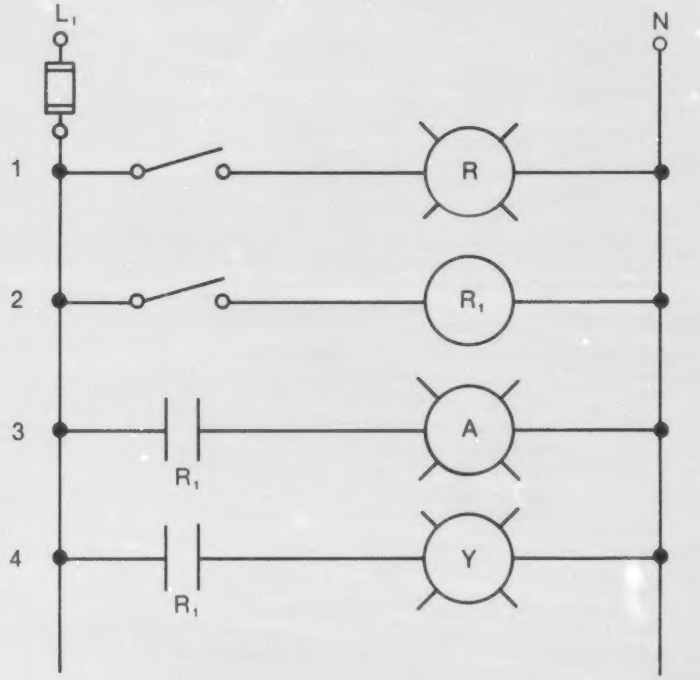
H. ______________________

I. ______________________

ELECTRICAL DIAGRAMS
UNIT III

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1


L1
N
1
2
3
4
R
R1
A
Y
R1
R1

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #2

A. Normally open push button (start)

B. Normally closed push button (stop)

C. Thermal overload relay

D. Auxilary contact

E. Line and control wiring terminal

F. Main contact

G. T2 motor lead terminal

H. Three-phase motor

I. Overload device switch

ELECTRICAL DIAGRAMS
UNIT III

TEST

NAME ______________________________ SCORE ______________

1. Match to their correct definitions terms associated with electrical diagrams. Write the correct numbers in the blanks. Terms and definitions are continued on the next page.

______a. Pilot device that delays closing or opening of a circuit for a specific time; may be motor driven, solenoid-actuated, or electric

______b. Control device with electric contactor and overload protection; designed to protect motor from voltage inrush during starting

______c. Manually operated multiposition switch

______d. Device that controls electrical apparatus from some distance

______e. Electromechanical device operated by a coil; uses contacts to make or break circuits

______f. Switch, manually operable plunger, button, or actuating device

______g. Device for protecting motor from overload current or voltage

______h. Starter designed to start motor at a reduced speed and build to full speed in preset steps

______i. Contactor operated electromechanically

______j. Momentarily operating; moving driven machine a small distance

______k. Function of magnetic control that connects equipment directly to line supply on starting

______l. Device without overload protection; repeatedly establishes and interrupts an electric power circuit

______m. Two different metals bonded to provide fast heat transfer to trip contacts by mechanical deflection

1. Bimetal
2. Multispeed starter
3. Push button
4. Contactor
5. Magnetic contactor
6. Timer
7. Selector switch
8. Full voltage control
9. Overload relay
10. Remote control
11. Jogging (inching)
12. Starter
13. Relay

TEST

_____n. Contact provided in addition to the main circuit contacts but operated with the main contacts

_____o. Pertaining to self-acting starter completely controlled by pilot switches or some other sensing device

_____p. Method of starting an electric motor by connecting it directly to supply line

_____q. Schematic consisting of single-phase and three-phase power lines; indicates power distribution and fuse and interrupter coordination

_____r. Schematic consisting of symbols and lines that indicate power source and how current flows through various parts of a control circuit

_____s. Schematic consisting of symbols and lines that indicate all connections and placement of all component parts in a device or circuit, including the power circuit wiring

14. Auxiliary contact
15. Across-the-line
16. One-line diagram
17. Wiring diagram
18. Ladder diagram (line diagram)
19. Automatic starting

2. State characteristics of wiring diagrams.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

3. State characteristics of ladder diagrams.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

TEST

4. State characteristics of one-line diagrams.

a. Power company one-line diagrams

1) ____

2) ____

3) ____

b. Industrial plant one-line diagrams

1) ____

2) ____

3) ____

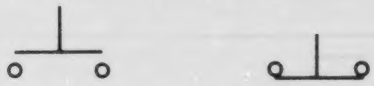
4) ____

5) ____

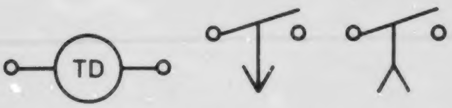
6) ____

5. Identify the following wiring and ladder diagram symbols. Write the correct names in the blanks.

Thermal overload relay
Time delay relay
Standard resistor
Standard push-button switch
Plugging switch
Limit switch (normally open)
Limit switch (normally closed)
Limit switch (held open)
Limit switch (held closed)
Two-wire pilot device
"Roto-push" selector push button, two-position selector ring switch
Three-position selector switch, mechanically coupled
Two-circuit push button
Two-position selector switch
Toggle-operated manual switch (wobble stick)
Three-position selector switch
Single-voltage transformer
Auto-transformer for reduced voltage starting
Single-voltage magnet coil
Contact (normally open)
Contact (normally closed)
Contact (timed open)
Contact (timed closed)
Standard fuse
Standard indicator light
Single-phase AC motor
Three-phase AC motor
Control relay

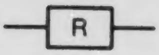


a. ______________________________

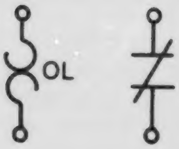


b. ______________________________

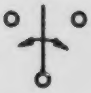
TEST



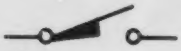
c. ______________________________



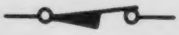
d. ______________________________



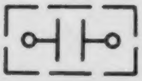
e. ______________________________



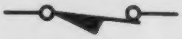
f. ______________________________



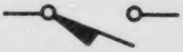
g. ______________________________



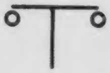
h. ______________________________



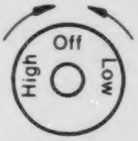
i. ______________________________



j. ______________________________

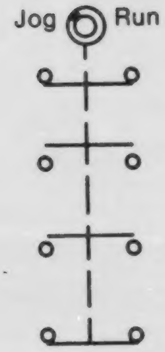


k. ______________________________

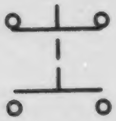

Off
High
Low

l. ______________________________

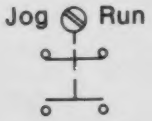
TEST



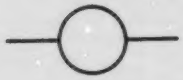
m. ______________________________



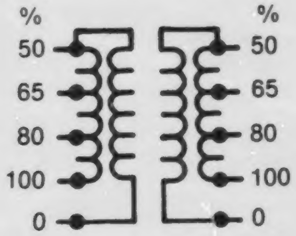
n. ______________________________



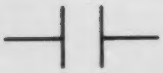
o. ______________________________



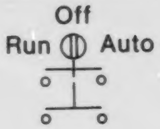
p. ______________________________


%
50
65
80
100
0
%
50
65
80
100
0

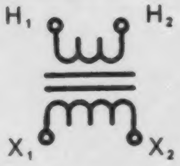
q. ______________________________



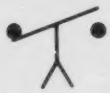
r. ______________________________


Off
Run
Auto

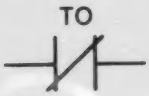
s. ______________________________



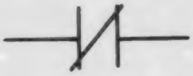
t. ______________________________



or

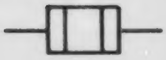


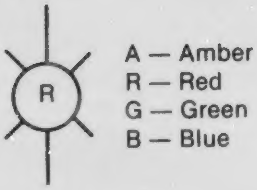
u. ______________________________



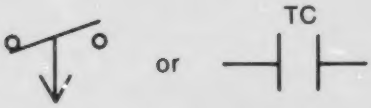
v. ______________________________

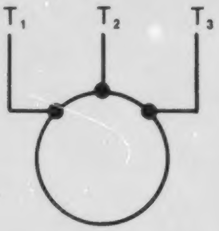
TEST



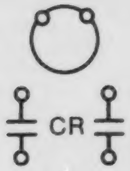


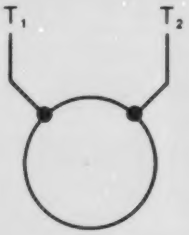
w. ______________________________ x. ______________________________





y. ______________________________ z. ______________________________





aa. ______________________________ bb. ______________________________

6. Arrange in order major steps in constructing a ladder diagram. Write a "1" before the first step, a "2" before the second step, and so on.

_____a. Connect circuit wires, keeping ladder rungs equidistant for ease of reading

_____b. Identify and label loads

_____c. Number rungs, and cross reference

_____d. Establish and label power lines

_____e. Identify and label control devices and contacts for each circuit

(NOTE: Test questions 7 and 8 list the assignment sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

7. Construct a basic ladder diagram.

8. Identify electrical symbols in a wiring diagram.

ELECTRICAL DIAGRAMS
UNIT III

ANSWERS TO TEST

1. a. 6
   b. 12
   c. 7
   d. 10
   e. 13
   f. 3
   g. 9
   h. 2
   i. 5
   j. 11
   k. 8
   l. 4
   m. 1
   n. 14
   o. 19
   p. 15
   q. 16
   r. 18
   s. 17

2. a. Show components in their approximate locations
   b. Provide guide for field wiring
   c. Use electrical symbols
   d. Show high and low voltage lines together
   e. Make circuits difficult to trace

3. a. Resemble a ladder
   b. Depict individual circuits as ladder rungs
   c. Use electrical symbols
   d. Separate high and low voltages
   e. Simplify circuit troubleshooting

4. a. Power company one-line diagrams
      1) Show electrical transmission or distribution lines
      2) Show sectionalizing points
      3) Show location of transformers
   b. Industrial plant one-line diagrams
      1) Show location of transformers

ANSWERS TO TEST

2) Show location of switches or breakers

3) Show location of fuses

4) Indicate size of fuses

5) Indicate size of loads

6) Indicate characteristics of loads

5. a. Standard push-button switch

b. Time delay relay

c. Standard resistor

d. Thermal overload relay

e. Plugging switch

f. Limit switch (held open)

g. Limit switch (normally closed)

h. Two-wire pilot device

i. Limit switch (held closed)

j. Limit switch (normally open)

k. Toggle-operated manual switch (wobble stick)

l. Three-position selector switch, mechanically coupled

m. "Roto-push" selector push button, two-position selector ring switch

n. Two-circuit push button

o. Two-position selector switch

p. Single-voltage magnet coil

q. Auto-transformer for reduced voltage starting

r. Contact (normally open)

s. Three-position selector switch

ANSWERS TO TEST

t. Single-voltage transformer

u. Contact (timed open)

v. Contact (normally closed)

w. Standard fuse

x. Standard indicator light

y. Contact (timed closed)

z. Three-phase AC motor

aa. Control relay

bb. Single-phase AC motor

6. a. 4

   b. 2

   c. 5

   d. 1

   e. 3

7. Evaluated to the satisfaction of the instructor

8. Evaluated to the satisfaction of the instructor

SOLID-STATE DEVICES
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to use manufacturer's recommendations to install, operate, check, and test selected solid-state electronic controls. The student will show this knowledge by completing assignment sheet, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with solid-state electronic devices.
2. Write meanings of abbreviations associated with solid-state electronic devices.
3. Name actions that can be monitored with a sensor.
4. Name types of signals that can be sent by sensors.
5. Name characteristics of solid-state relays.
6. Describe types of solid-state devices.
7. Match solid-state components to their correct uses.
8. Match types of logic functions to their correct meanings.
9. Identify logic functions.
10. Arrange in order the logic sequence of a three-wire motor control.
11. Determine the status of logic gate output signals.
12. Demonstrate the ability to
    a. Install and operate a selected modulated retroreflective controller.
    b. Install and operate a selected Hall-effect sensor.

SOLID-STATE DEVICES
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

  A. Make transparencies.

  B. Provide students with objective sheet.

  C. Discuss unit and specific objectives.

  D. Provide students with information, assignment, and job sheets.

  E. Discuss information, assignment, and job sheets.

    1. Discuss terms related to solid-state devices, using Information Sheet, Section I. Show samples of SCRs, Triacs, photocells, and other electronic components to the students.

    2. Discuss meanings of abbreviations related to solid-state electronic devices, using Information Sheet, Section II. If possible, acquire a solid-state relay, as well as a contactor to show the similarities and differences between the two. Have students note the size of the contactor. Explain that the solid-state relay is silent in its operation while the contactor produces some noise.

    3. Discuss actions that can be monitored with solid-state sensors, using Information Sheet, Section III. Show students several examples of solid-state sensors, such as photocells that monitor light, as well as some proximity controls that monitor anything entering the area.

    4. Discuss types of signals that can be sent by sensors, using Information Sheet, Section IV. Be sure to discuss the advantages of solid-state sensors, as compared to electromechanical relays, especially the features of no-voltage, no-current turn on, and varying voltages.

    5. Discuss characteristics of solid-state relays, using Information Sheet, Section V. Include some of the effects of attempting to mix electromechanical relays and solid-state equipment. Have the students research on their own some of the characteristics of both electromechanical and solid-state relays. Have them draw a comparison chart in order to see the benefits and the drawbacks of each type.

SUGGESTED ACTIVITIES

6. Discuss types of solid-state devices, using Information Sheet, Section VI, Transparency #1, and Job Sheets #1 and #2. Discuss particular uses of each type of device: photocells for counting and alarm systems, modular or LED controls for alarm systems that detect persons in building, and the Hall-effect controller for a number of industrial applications from counting to speed adjustment calculations.

7. Discuss solid-state components and their uses, using Information Sheet, Section VII. Show students samples of the actual devices. Also, show students equipment in which these devices are in use. Explain to the students the need and purpose of each device discussed.

8. Discuss logic functions and their correct meanings, using Information Sheet, Section VIII. Make sure that students know that the names for each function are applicable not only to solid-state, but also to electromechanical functions. The use of the AND/OR, NAND/NOR, and NOT logic functions can be applied to both sides of a control system: solid-state and electromechanical.

9. Discuss the logic function symbols, using Information Sheet, Section IX, Transparency #2, and Assignment Sheet #1. Stress the importance of being able to readily identify each symbol and its function, as well as the input and output status of each. Present the students with copies of schematics so that they can see the symbols and understand how the accompanying circuitry operates.

10. Discuss logic sequence of a three-wire motor control, using Information Sheet, Section X. Note the similarities and differences between a control of this nature and a control using electromechanical equipment. Show students a solid-state three-wire system and an electromechanical three-wire system, so that they may compare and contrast both systems.

F. Give test.

II. Instructional materials

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM #1 — Hall-Effect Principle

2. TM #2 — Logic Function Symbols

D. Assignment Sheet #1 — Determine the Status of Logic Gate Output Signals

SUGGESTED ACTIVITIES

E. Answers to assignment sheet

F. Job sheets

1. Job Sheet #1 — Install and Operate a Selected Modulated Retroreflective Controller

2. Job Sheet #2 — Install and Operate a Selected Hall-Effect Sensor

G. Test

III. Unit references — Rockis, Gary, and Glen Mazur. *Electrical Motor Controls*. Alsip, Illinois: American Technical Publishers, Inc., 1982.

SOLID-STATE DEVICES
UNIT I

INFORMATION SHEET

I. Terms and definitions

  A. Static — Pertaining to or characterized by a fixed or stationary control

  B. Static control — Device that operates or controls without moving parts

  C. Sensor — Device that detects conditions or changes in position and sends this information to an electronic controller

  D. Control module — Electronic device that receives information from sensor, makes decisions, and sends signals for action or lack of action

  E. Signal — Bit of information sent to a controller by a sensor; a command from the controller for an action

  F. Decision-maker — Control module that determines what work is needed and in what sequence the action is to occur

  G. Logic function — Behavior of devices in a predetermined manner

  H. Photoelectric cell — Light-sensitive solid-state device

  I. Silicon-controlled rectifier — Device used for on/off control on gate circuit

  J. Triac — Trademark of the General Electric Company for a gate-controlled semiconductor switch designed for alternating-current power control; constructed of two silicon-controlled rectifiers connected in inverse-parallel

II. Abbreviations associated with solid-state electronic devices

  A. SCR — Silicon-controlled rectifier

  B. SSR — Solid-state relay

  C. EMR — Electromechanical relay

  D. LED — Light-emitting diode

III. Actions that can be monitored with a sensor

  A. Light

  B. Liquid level

  C. Weight

INFORMATION SHEET

- D. Temperature
- E. Proximity
- F. Pressure
- G. Open or closed status of circuit
- H. Speed

IV. Types of signals that can be sent by sensors

- A. Voltage
- B. No voltage
- C. Voltage change
- D. Current
- E. No current
- F. Current change
- G. Varying voltages
- H. Varying currents

V. Characteristics of solid-state relays

- A. Provide arcless switching
- B. Are compatible with electronic circuits
- C. Are adversely affected by heat
- D. Are shock resistant
- E. Are susceptible to transients
- F. Provide silent operation
- G. Cannot withstand current surges
- H. Have fast response time
- I. Have long life expectancy

INFORMATION SHEET

VI. Descriptions of various types of solid-state devices

  A. Photoelectric controls

    1. Retroreflective unit

      a. Operates with direct or alternating current

      b. Controls on/off-type actions

      EXAMPLES: Night lights, doors, counters, conveyors

      c. Operates up to 125 times per second

    2. Modular LED controls

      a. Operate with direct or alternating current

      b. Operate on invisible infrared beam

      c. Operate on a wide range and up to 2,500 times per second

      d. Require on/off amplifiers

      e. Penetrate foggy, dusty, or other poor-visibility conditions

  B. Hall-effect controller (Transparency #1)

    1. Is completely solid state

    2. Is activated by a magnetic field

    3. Operates up to 30,000 times per second

    4. Is not affected by light, dust, or dirt

    5. Is not influenced by nonferrous materials

    6. Offers a wide range of applications

    EXAMPLES: Speed sensing, conveyor belt operation, counting, switch operation, length measurement, leveling (degree of tilt measurement)

7. Offers relatively simple troubleshooting

EXAMPLES: Proper spacing of magnet, correct direct-current input

VII. Solid-state components and their uses

(NOTE: This list includes selected uses of each component. Each component may have several additional capabilities.)

A. Diode — Used to rectify alternating current to direct current

B. Zener diode — Used as a voltage regulator

C. Transistor — Used as an amplifier or a switch

D. Silicon-controlled rectifier (SCR) — Used to control speed of direct-current motors

E. Triac — Used to control speed of alternating-current motors

F. Light-emitting diode (LED) — Used to give visual indication of power

VIII. Types of logic functions and their meanings

A. AND — Logic function that requires all inputs to be present to have an output

(NOTE: The AND logic function is comparable to normally-open switches in series.)

B. OR — Logic function that guarantees output when any one or more inputs are present

(NOTE: The OR logic function is comparable to normally-open switches in parallel.)

C. NOT — Logic function that inverts signal and output

(NOTE: When there is no output, input signal is present; when there is output, input signal is not present.)

D. NOR (NOT-OR) — Logic function in which output is low when either of the inputs, but not both, is high

(NOTE: The NOR logic function is the same as OR with output inverted.)

INFORMATION SHEET

E. NAND (NOT-AND) — Logic function in which both inputs must be high for output to be low

(NOTE: The NAND logic function is the same as AND with output inverted.)

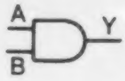
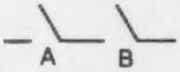
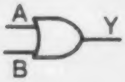
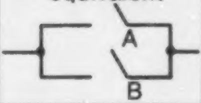
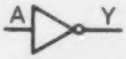
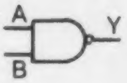
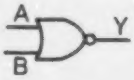
F. Temporary memory (storage) — Function that remembers condition of its output as long as power is on

G. Retentive memory (storage) — Function that remembers condition of its output even after power is off

IX. Logic functions and their symbols (Table 1)

(NOTE: A "1" indicates a signal, and "0" indicates no signal.)

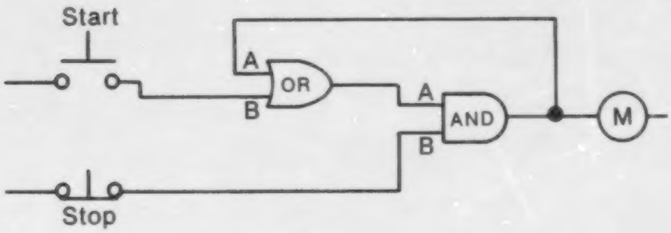
TABLE 1

Function	Symbol	Truth Table		Comments
		Inputs	**Output**	
AND		A B 1 1 1 0 0 1 0 0	Y 1 0 0 0	Mechanical equivalent 
OR		A B 1 1 1 0 0 1 0 0	Y 1 1 1 0	Mechanical equivalent 
NOT		A 1 0	Y 0 1	Inverter
NAND		A B 1 1 1 0 0 1 0 0	Y 0 1 1 1	Same as AND with output inverted
NOR		A B 1 1 1 0 0 1 0 0	Y 0 0 0 1	Same as OR with output inverted

INFORMATION SHEET

X. Logic sequence of a three-wire motor control (Figure 1)

FIGURE 1



A. Normally-closed stop button sends signal to AND from gate point B; both A and B must have signal to cause output

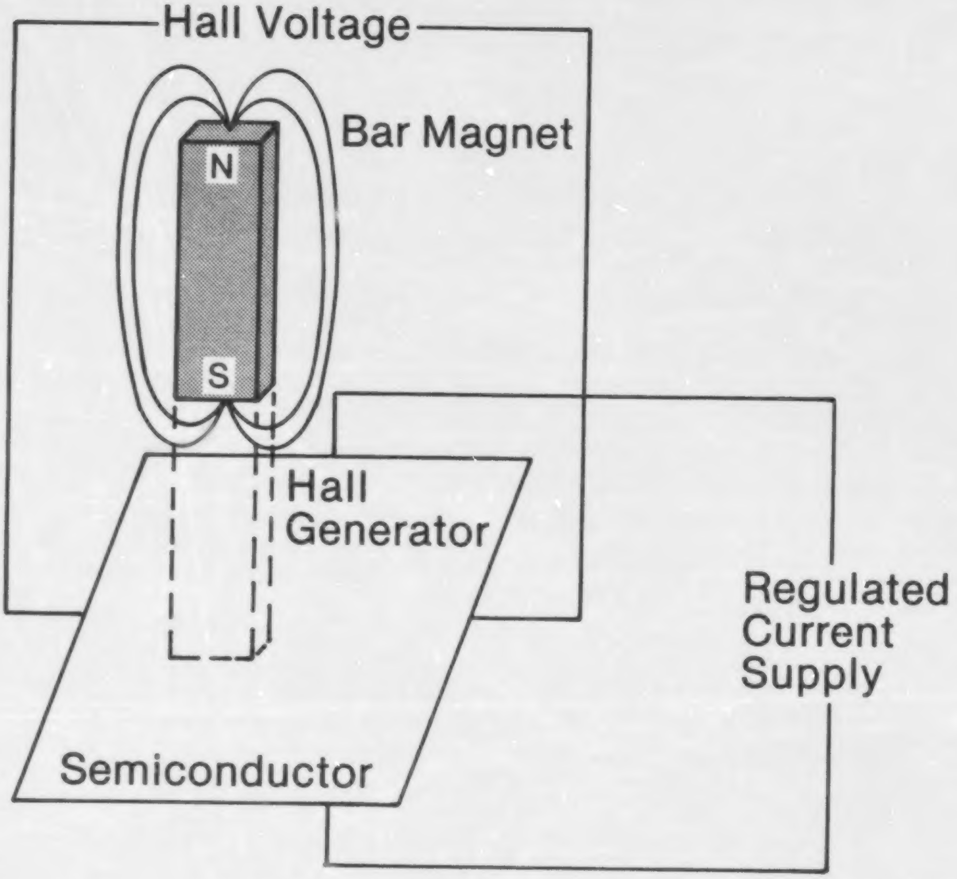
B. When normally-open start button is closed, signal is sent to OR gate, point B; OR gate sends signal to AND gate, point A

C. AND gate sends signal to M because A and B signals are both present

D. Output signal from AND gate also returns to OR gate, point A and causes it to remain on

E. When stop button is opened, signal to AND gate, point B is stopped; output signal stops, dropping M as well as point A of OR gate

Hall-Effect Principle

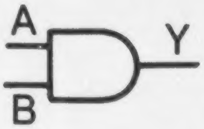
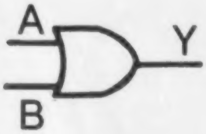
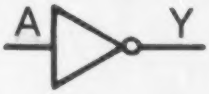
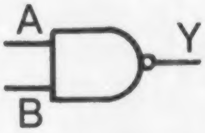
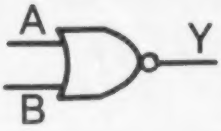

Hall Voltage
Bar Magnet
N
S
Hall Generator
Regulated Current Supply
Semiconductor

Magnet at Furthest Point — Voltage at Minimum

As Magnet Approaches — Voltage Increases

Magnet at Closest Point — Voltage at Maximum

Logic Function Symbols

Function	Symbol	Truth Table		
		Inputs		Output
AND		A 1 1 0 0	B 1 0 1 0	Y 1 0 0 0
OR		A 1 1 0 0	B 1 0 1 0	Y 1 1 1 0
NOT		A 1 0		Y 0 1
NAND		A 1 1 0 0	B 1 0 1 0	Y 0 1 1 1
NOR		A 1 1 0 0	B 1 0 1 0	Y 0 0 0 1

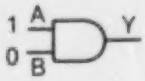
SOLID-STATE DEVICES
UNIT I

ASSIGNMENT SHEET #1 — DETERMINE THE STATUS OF LOGIC GATE OUTPUT SIGNALS

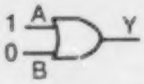
NAME ____ SCORE ________________

An industrial electrician's ability to check logic gates is dependent on knowing proper logic names and requirements.

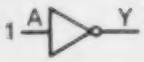
Determine the status of the output signals for the following logic gates. Write a "1" to indicate on and a "0" to indicate off.



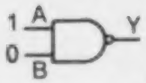
__________A.



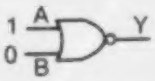
__________B.



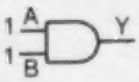
__________C.



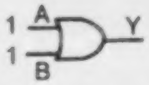
__________D.



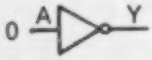
__________E.



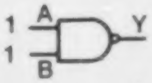
__________F.



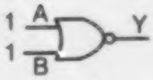
__________G.



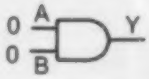
__________H.



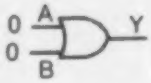
__________I.



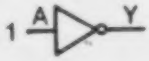
__________J.



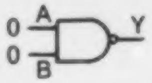
__________K.



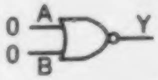
__________L.



__________M.



__________N.



__________O.

SOLID-STATE DEVICES
UNIT I

ANSWERS TO ASSIGNMENT SHEET

Assignment Sheet #1

A. 0

B. 1

C. 0

D. 1

E. 0

F. 1

G. 1

H. 1

I. 0

J. 0

K. 0

L. 0

M. 0

N. 1

O. 1

SOLID-STATE DEVICES
UNIT I

JOB SHEET #1 — INSTALL AND OPERATE A SELECTED MODULATED RETROREFLECTIVE CONTROLLER

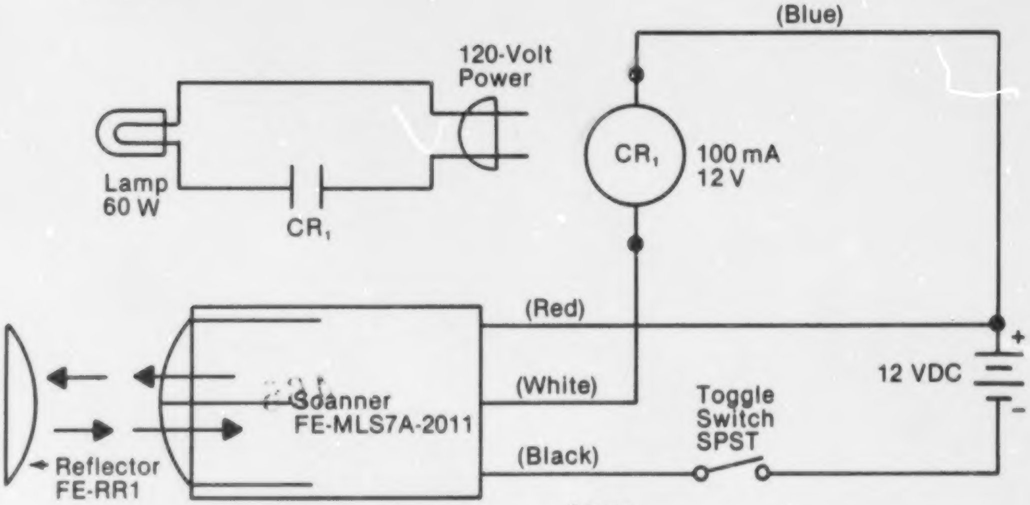
I. Equipment and materials

- A. Scanner Microswitch, #FE-MLS7A-2011
- B. Reflector Microswitch, #FE-RR1
- C. Pouch tools
- D. 12-volt DC power supply
- E. 120-volt power supply
- F. 10 feet of #18 TFF wire
- G. Lamp socket, keyless with medium base
- H. 60-watt lamp
- I. 12-volt DC control relay coil, 100 milliampere or less
- J. Colored tape, red, white, black, and blue

II. Procedure

- A. Study circuit illustrated in Figure 2

FIGURE 2


(Blue)
120-Volt Power
CR1
100 mA
12 V
Lamp 60 W
CR1
(Red)
(White)
(Black)
+
12 VDC
−
Toggle Switch SPST
Scanner FE-MLS7A-2011
Reflector FE-RR1

JOB SHEET #1

B. Hook up lamp socket with relay contacts and plug

C. Locate reflector

D. Using alignment indicator, position scanner to throw beam on reflector

E. Color-code wires with the colored tapes

F. Connect white wire to relay coil

G. Connect blue wire to relay coil and positive terminal of DC power supply

H. Connect red wire to DC power supply

I. Connect black wire through toggle switch to negative terminal of DC power supply

J. Close switch to project beams into reflector

(NOTE: Closing the switch energizes the scanner.)

K. Plug lamp into 120-volt power supply

L. Break beam by passing hand or object between reflector and scanner

(NOTE: Light should go off while beam is interrupted.)

M. Open toggle switch and dismantle apparatus

N. Clean work area; put away equipment and materials

SOLID-STATE DEVICES
UNIT I

JOB SHEET #2 — INSTALL AND OPERATE A SELECTED HALL-EFFECT SENSOR

I. Equipment and materials

A. DC power supply, 4.5 to 5.5 volt or 6 to 16 volt

B. Hall-effect sensor, Microswitch, catalog #5SS

C. Magnet-Microswitch, catalog #101 MG 3

D. Resistor, 300 ohm

E. Resistor, 10 kohm

F. Triac, #2N6071

G. Keyless lamp socket

H. Lamp, 60 watt, 120 volt

I. 20 feet of #18 TFF wire

J. Connection to 120-volt power supply

K. Pouch tools

L. Several assorted quick-connecting terminals

M. Toggle switch, SPST

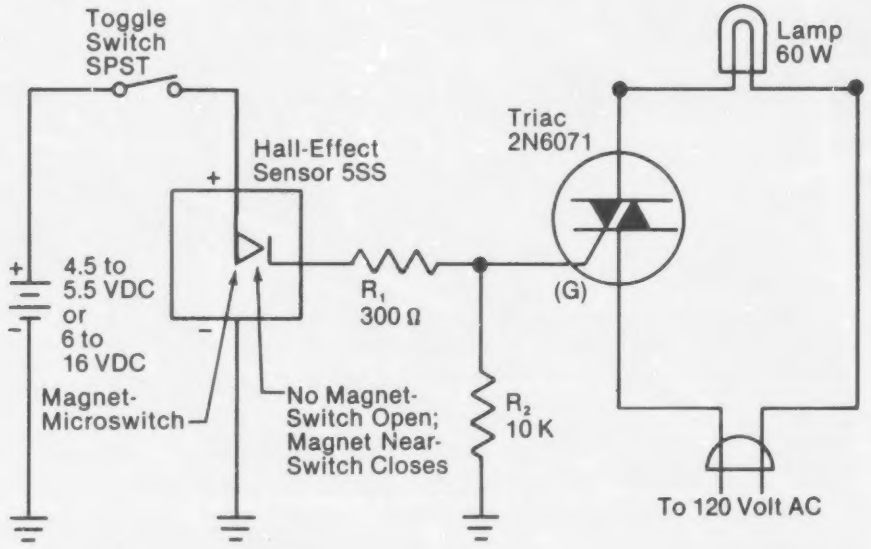
N. Bar magnet

JOB SHEET #2

II. Procedure

A. Study circuit illustrated in Figure 3

FIGURE 3


Toggle Switch SPST
Lamp 60 W
Triac 2N6071
Hall-Effect Sensor 5SS
+
+
4.5 to 5.5 VDC or 6 to 16 VDC
−
−
R_1 300 Ω
(G)
Magnet-Microswitch
No Magnet-Switch Open; Magnet Near-Switch Closes
R_2 10 K
To 120 Volt AC

B. Connect lamp socket to plug and Triac

C. Place Hall-effect sensor in position

D. Install resistors

E. Connect Hall-effect sensor to ground and to toggle switch

F. Connect negative terminal of DC power supply to ground

G. Connect positive terminal of DC power supply to toggle switch

H. Plug lamp into 120-volt power supply

I. Close DC toggle switch

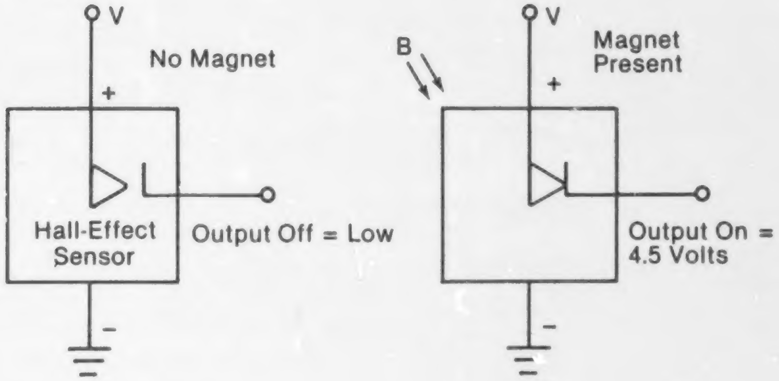
(NOTE: No action will be visible.)

JOB SHEET #2

J. Bring bar magnet near enough to Hall-effect sensor to cause triggering of Triac (Figure 4)

(NOTE: The light will come on. The Hall voltage is dependent on the presence of the magnetic field and on the current flowing in the element. If either the current or the magnetic field is removed, the output of the Hall generator is zero.)

FIGURE 4


V
No Magnet
+
Hall-Effect Sensor
Output Off = Low
−
B
V
Magnet Present
+
Output On = 4.5 Volts
−

Used with permission of MICROSWITCH, a division of Honeywell, Freeport, Illinois.

K. Open toggle switch and dismantle apparatus

L. Clean work area; put away equipment and materials

SOLID-STATE DEVICES
UNIT I

TEST

NAME _______________________________________ SCORE ______________

1. Match to their correct definitions terms associated with solid-state electronic devices. Write the correct numbers in the blanks.

_____a. Pertaining to or characterized by a fixed or stationary control

_____b. Device that operates or controls without moving parts

_____c. Device that detects conditions or changes in position and sends this information to an electronic controller

_____d. Electronic device that receives information from sensor, makes decisions, and sends signals for action or lack of action

_____e. Bit of information sent to a controller by a sensor; a command from the controller for an action

_____f. Control module that determines what work is needed and in what sequence the action is to occur

_____g. Behavior of devices in a predetermined manner

_____h. Light-sensitive solid-state device

_____i. Trademark of the General Electric Company for a gate-controlled semiconductor switch designed for alternating-current power control; constructed of two silicon-controlled rectifiers connected in inverse-parallel

_____j. Device used for on/off control on gate circuit

1. Signal
2. Logic function
3. Static
4. Control module
5. Sensor
6. Photoelectric cell
7. Static control
8. Decision-maker
9. Silicon-controlled rectifier
10. Triac

TEST

2. Write meanings of abbreviations associated with solid-state electronic devices.

    a. SCR — ____________________

    b. SSR — ____________________

    c. EMR — ____________________

    d. LED — ____________________

3. Name five actions that can be monitored with a sensor.

    a. ____________________

    b. ____________________

    c. ____________________

    d. ____________________

    e. ____________________

4. Name five types of signals that can be sent by sensors.

    a. ____________________

    b. ____________________

    c. ____________________

    d. ____________________

    e. ____________________

5. Name four characteristics of solid-state relays.

    a. ____________________

    b. ____________________

    c. ____________________

    d. ____________________

TEST

6. Describe the following types of solid-state devices.

   a. Photoelectric controls

      1) Retroreflective unit

      2) Modular LED controls

   b. Hall-effect controller

TEST

7. Match solid-state components to their correct uses. Write the correct numbers in the blanks.

_____a. Used as a voltage regulator

_____b. Used to control speed of alternating-current motors

_____c. Used to give visual indication of power

_____d. Used to rectify alternating current to direct current

_____e. Used to control speed of direct-current motors

_____f. Used as an amplifier or a switch

1. Diode
2. Zener diode
3. Transistor
4. Silicon-controlled rectifier (SCR)
5. Triac
6. Light-emitting diode (LED)

8. Match types of logic functions to their correct meanings. Write the correct numbers in the blanks.

_____a. Logic function that requires all inputs to be present to have an output

_____b. Logic function that guarantees output when any one or more inputs are present

_____c. Logic function in which output is low when either of the inputs, but not both, is high

_____d. Logic function that inverts signal and output

_____e. Logic function in which both inputs must be high for output to be low

_____f. Function that remembers condition of its output as long as power is on

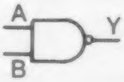
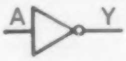
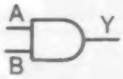
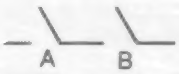
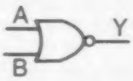
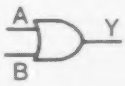
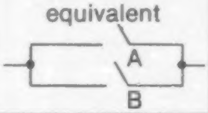
_____g. Function that remembers condition of its output even after power is off

1. Temporary memory
2. NOT
3. AND
4. Retentive momory
5. OR
6. NOR (NOT-OR)
7. NAND (NOT-AND)

TEST

9. Identify the following logic functions by completing the chart below. Write the correct names in the blanks.

AND **NAND**
OR **NOR**
NOT

Function	**Symbol**	**Truth Table**		**Comments**
		Inputs	**Output**	
a.________		A B 1 1 1 0 0 1 0 0	Y 0 1 1 1	Same as AND with output inverted
b.________		A 1 0	Y 0 1	Inverter
c.________		A B 1 1 1 0 0 1 0 0	Y 1 0 0 0	Mechanical equivalent 
d.________		A B 1 1 1 0 0 1 0 0	Y 0 0 0 1	Same as OR with output inverted
e.________		A B 1 1 1 0 0 1 0 0	Y 1 1 1 0	Mechanical equivalent 

10. Arrange in order the logic sequence of a three-wire motor control. Write a "1" before the first step, a "2" before the second step, and so on.

______a. AND gate sends signal to M because A and B signals are both present

______b. When normally-open start button is closed, signal is sent to OR gate, point B; OR gate sends signal to AND gate, point A

______c. Normally-closed stop button sends signal to AND from gate point B; both A and B must have signal to cause output

TEST

_____d. Output signal from AND gate also returns to OR gate, point A and causes it to remain on

_____e. When stop button is opened, signal to AND gate, point B is stopped; output signal stops, dropping M as well point A of OR gate

(NOTE: Test questions 11 and 12 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

11. Determine the status of logic gate output signals.

12. Demonstrate the ability to

    a. Install and operate a selected modulated retroreflective controller.

    b. Install and operate a selected Hall-effect sensor.

SOLID-STATE DEVICES
UNIT I

ANSWERS TO TEST

1. a. 3
   b. 7
   c. 5
   d. 4
   e. 1
   f. 8
   g. 2
   h. 6
   i. 10
   j. 9

2. a. Silicon-controlled rectifier
   b. Solid-state relay
   c. Electromechanical relay
   d. Light-emitting diode

3. Answer should include any five of the following
   a. Light
   b. Liquid level
   c. Weight
   d. Temperature
   e. Proximity
   f. Pressure
   g. Open or closed status of circuit
   h. Speed

ANSWERS TO TEST

4. Answer should include any five of the following
   - a. Voltage
   - b. No voltage
   - c. Voltage change
   - d. Current
   - e. No current
   - f. Current change
   - g. Varying voltages
   - h. Varying currents

5. Answer should include any four of the following
   - a. Provide arcless switching
   - b. Are compatible with electronic circuits
   - c. Are adversely affected by heat
   - d. Are shock resistant
   - e. Are susceptible to transients
   - f. Provide silent operation
   - g. Cannot withstand current surges
   - h. Have fast response time
   - i. Have long life expectancy

6. Description should include the following
   - a. Photoelectric controls
     - 1) Retroreflective unit
       - a) Operates with direct or alternating current

ANSWERS TO TEST

b) Controls on/off-type actions

c) Operates up to 125 times per second

2) Modular LED controls

a) Operate with direct or alternating current

b) Operate on invisible infrared beam

c) Operate on a wide range and up to 2,500 times per second

d) Require on/off amplifiers

e) Penetrate foggy, dusty, or other poor-visibility conditions

b. Hall-effect controller

1) Is completely solid state

2) Is activated by a magnetic field

3) Operates up to 30,000 times per second

4) Is not affected by light, dust, or dirt

5) Is not influenced by nonferrous materials

6) Offers a wide range of applications

7) Offers relatively simple troubleshooting

7. a. 2

b. 5

c. 6

d. 1

e. 4

f. 3

ANSWERS TO TEST

8. a. 3
   b. 5
   c. 6
   d. 2
   e. 7
   f. 1
   g. 4

9. a. NAND
   b. NOT
   c. AND
   d. NOR
   e. OR

10. a. 3
    b. 2
    c. 1
    d. 4
    e. 5

11. Evaluated to the satisfaction of the instructor

12. Performance skills evaluated to the satisfaction of the instructor

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